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PAPERS

ON

SQUADRONS OF EVOLUTIONS

AND

THE RECENT DEVELOPMENT OF NAVAL MATÉRIEL.

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INTRODUCTORY NOTE.

In the preparation of General Information, Series No. V, it has been the aim of the Office of Naval Intelligence to indicate the methods employed by foreign naval powers in the development of the skill and training of the personnel by means of squadrons of evolutions and to notice the progress recently made in the construction of naval matériel.

The first article in this number contains an account of the naval manœuvers conducted during the past year by the squadrons of evolutions of different nations.

Chapter II embodies notes on the evolution of the principal types of modern war vessels representing the leading schools of naval architects abroad, with comparisons of the relative efficiency of vessels recently built or laid down, and other notes on ship designs.

Chapter III contains a historical sketch of the development of the torpedo-boat from its earliest invention to its present wonderful state of perfection. Chapter IV is a translation of an article on the torpedo boat by Mr. J. A. Normand, the distinguished French engineer and the builder of the greater number of French torpedo-boats. These papers should be of valuable assistance to naval constructors and others who may be engaged in designing and building our own much-needed boats.

Chapter V indicates the character of steam trials and the methods of conducting them in the English service and represents the performance of different typical vessels, giving speed curves based upon actual performance, but brought to common displacements ranging from 1,500 to 10,000 tons.

Chapter VI treats of liquid fuel as applied to sea-going vessels, a subject which is attracting much attention abroad and which it is to be hoped will soon be practically considered by our Government for the benefit of the naval and commercial marine.

Chapter VII describes the methods employed in carrying on the rolling experiments on board the U. S. S. Tennessee in November last and compares her rolling characteristics with those of foreign vessels.

Chapter VIII completes the narrative of the important naval operations under Admiral Courbet during the Franco-Chinese war.

The number concludes with notes compiled from Parliamentary reports, budgets, and professional publications and journals of the countries to which they relate, in reference to the progress made during the year in the design, construction, or performance of vessels and other weapons used in naval warfare.

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I.

NAVAL MANŒUVERS AND SQUADRONS OF EVOLUTIONS OF THE LAST YEAR.

NAVAL MANŒUVERS AND SQUADRONS OF EVOLUTIONS OF THE LAST YEAR.

During the past year or two a marked advance has been noticeable in the system of training and instruction in the fleets of all naval powers, whereby the habit of fostering smartness and activity aloft to the detriment or comparative neglect of preparation for battle and service in war has gradually given place to more earnest attention to the latter. Indeed, the gradual reduction in spars and sail area in modern vessels and the great dissimilarity in the rigs of those now composing fleets or squadrons has naturally suggested some other system of competitive drill and instruction whereby the efficiency of vessels may be judged. The fact is that the seaman of to-day can no longer be trained as was the seaman of twenty or even ten years since. Modern men-of-war have become complicated fighting machines, and it is necessary to carefully and intelligently instruct the personnel in all the various and precise appliances which in time of war it is expected to use. Such a training must be persistent and with but one object in view—service in time of war and battle.

Such training involves the skillful handling of vessels moving at high speeds, the accurate pointing of guns whose discharge represents the loss of a large sum of money and opportunity or the gain of dealing a serious blow to one's adversary; it demands that the seaman shall be skillful and ready in the manipulation of the machine gun or magazine rifle with which he is armed, so that he may take advantage of its great power at critical moments; that he be acquainted with the care and manipulation of a delicate piece of mechanism in the form of a torpedo; that he be somewhat acquainted with the principles of electricity and their application to the discharge of the weapons intrusted to his charge, as well as to their application to lighting and signaling.

It is true that the personal element, shown in the qualities of character, courage, nerve, good judgment and skill will predominate in future naval engagements as well as in those past, and that a man-of-war in battle or in danger will be worth just what her commander is—nothing more; but presuming the commander to be of the proper stuff, the machine under his command must, as the result of careful deliberation in design and construction and earnestness in the training of its personnel, be in perfect working condition to successfully meet the modern vessel of the day.

For the purpose, then, of teaching the art of war all naval powers indulge at considerable expense once in each year in a series of naval manœuvers, during which squadrons of evolutions carry out some plan of operations as if engaged in actual warfare. Such manœuvers are no longer confined to a few of the greatest powers, for, in addition to the beginning recently made by ourselves, the fleets of England, France, Italy, Germany, Russia, Austria, Norway, and Brazil have within the year engaged in them, as the following will indicate.

The experience gained in this mode of instruction furnishes the most valuable school for the study of tactics and the handling of vessels of different types. However poor the vessels composing the squadron may be, opportunities are afforded for the development of nerve and judgment, the attainment of the habit of readily estimating distances, and the acquirement of a knowledge of the movement of vessels in relation to fixed or moving objects which cannot be so well obtained by sea officers in any other manner; and in those fleets composed of modern ships accompanied by torpedo-boats the game of war is played in a most approved and realistic manner. It has been the custom of foreign powers not to permit the presence of strangers during these manœuvers, but the service journals usually give a general description of them, and Admiral Hornby's squadron was accompanied by the "war correspondents" (?) of the great leading London dailies. Such accounts and reports furnish the basis of this article.

ENGLAND.

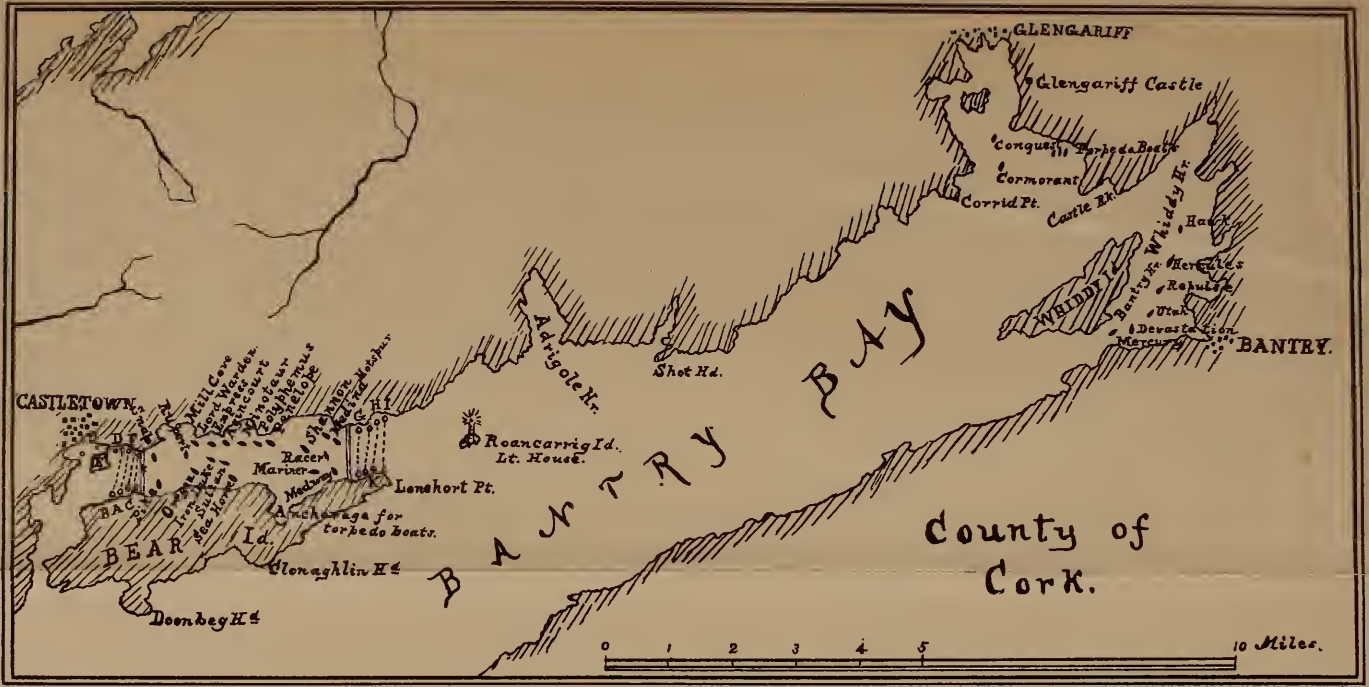
THE PARTICULAR SERVICE SQUADRON OF EVOLUTIONS.

[June–July, 1885.]

The unusual excitement into which England was thrown by the angry discussion of the Afghan boundary question and the great naval preparations which were made necessary by the probability of war with Russia in the spring of 1885 occasioned the arming and commissioning of a greater fleet than had been gathered in English waters for a number of years. The sudden subsidence of the war cloud and the desirability of holding in readiness this formidable array of vesssels until peace was fully assured afforded the rare opportunity of undertaking naval operations on a large scale, of testing the efficiency of the fleet and its component parts, and of settling questions of modern tactics upon which opinions widely differed.

Accordingly, on the 9th of June, 1885, the particular service squadron, under the command of Admiral Hornby, left Portland. The squadron at this time was composed of—

First Division.—Minotaur (flagship of Admiral Hornby, commander-in-chief), Polyphemus, Shannon, and Lord Warden.



THE PARTICULAR SERVICE SQUADRON.

▨ Land. | —— Booms. | .... Indicate observation mines. |

●○○○○○○○○○○ Electro-mechanical, electro-contact, and boat mines. |

A. B. C. D. E. F. G. H. I. K. Positions of observation, with batteries of machine guns and field pieces.

Second Division.—Agincourt (flag of Rear-Admiral Hoskins), Hotspur, Devastation, and Iron Duke.

Third Division.—Hercules (flag of Rear-Admiral Whyte), Ajax, and Sultan.

(All armored.)

The Mercury, Conquest, Racer, and Mariner preceded the squadron towards the Irish coast. The Oregon (Cunarder) was left to bring forward the mails.

The Hecla, torpedo supply vessel, and eight torpedo-boats Nos. 2, 3, 4, 5, 12, 13, 21, and 22, accompanied the squadron.

Torpedo-boats Nos. 2, 3, 4, 5, 12, and 13 are 86 feet long; 25 to 30 tons displacement.

Nos. 21 and 22 are 113-foot boats, of about 60 tons displacement.

After leaving Portland the squadron was exercised in tactics, and at night proceeded in two columns.

On the passage to Bantry Bay two or three accidents occurred to the torpedo flotilla, and it was thought that had the weather been at all bad more defects would have been discovered.

Almost immediately after leaving Portland the machinery of No. 4 gave out, and she was taken in tow by the Hecla until repaired. No. 8 sprung a leak and was towed in under the land and repaired during the night. Another boat was disabled for a short time, but from no serious defect. [The size and date of design, about 1879, of these boats must not be lost sight of.] It was said that though the weather was fine, their decks were generally wet, that when steaming fast they were constantly covered with sheets of spray, and that in heavy weather they could not with safety steam fast nor approach a vessel unobserved. The waves breaking over their bows betray their presence and the telltale trail of smoke attracts attention to them.

Most of the torpedo-boats were coaled by the vessels to which they were attached, and this operation was attended with much difficulty although the sea was smooth.

On the 10th the Mercury, Conquest, Racer, and Mariner joined the squadron, and were employed as scouts. Preparations were made for entering and defending Bantry Bay. Light spars and rigging were sent down.

On the 11th the squadron anchored behind Bere Island, in Bantry Bay.

Berehaven, the scene of operations, is a well-sheltered anchorage lying between Bere Island and the north shore of Bantry Bay, forming a strait some 6 miles long and three-quarters of a mile wide, with a narrow entrance at the western end. It may be entered from either end, at any stage of the tide, by vessels of any draught. The surrounding hills vary in height from 300 to 3,000 feet, and the harbor affords ample room for the largest squadron. The shores are rocky and afford few good landing places.

The scheme to be observed may be briefly stated. The surrounding shores are to be considered as an enemy's country, and that for strategic reasons the British squadron has occupied the harbor. The enemy is supposed to be well supplied with torpedo-boats and the efforts of the ships are to be directed toward protecting themselves against attacks from these. Booms are to be placed across the entrances to the anchorage, and batteries are to be erected on shore for 20-pounders, to be used to flank the booms and mine fields placed outside of the former. In addition to the batteries gunboats are to be stationed to defend the booms and mines.

The eastern entrance was barred by a boom nearly a mile in length, formed of a double row of yards, masts, and 5-inch steel hawsers lashed together, buoyed in places, and securely moored. The boom at the western entrance was similar to the first and each was faced by a broad field of gun-cotton mines, some which were to be exploded by contact and others by electric control on shore.

The boom and defenses having been completed by the 15th and the squadron now consisting of the Minotaur, Hercules, Agincourt, Shannon, Sultan, Lord Warden, Penelope, Iron Duke, Repulse, (broadside armored ships), Rupert, Ajax, Hotspur, Devastation, Polyphemus, (armored turret-ships and rams), Hecla, Cormorant, Racer, Mariner, Conquest, Mercury, Hawk, (unarmored), Admiral Hornby proceeded to carry out further operations upon the idea that, having established and defended a temporary force for offensive movements along the coast, it was necessary for the squadron to protect itself against attacks from a powerful fleet known to be in the offing, whose advanced line of cruisers or scouts were within a short distance of the coast. These scouts were represented by the Conquest, Mercury, Cormorant, Mariner, and Racer, and some first-class torpedo-boats.

In order to check the operations of these and prevent their close approach a fleet of torpedo boats was sent out each night to keep the enemy's cruisers in sight and to harass their movements as much as possible. In this outpost duty the advantage was usually adjudged to the cruisers.

On the night of the 16th a skillful attempt was made by some of the armored vessels to run the blockade, supposed to be maintained by the scouts above mentioned which had been sent out of the harbor before nightfall.

At 11 p. m., the weather being clear, the Minotaur, Shannon, and Hotspur slipped their cables, and, the flagship leading, steamed slowly through a gap which had been opened in the eastern boom defense. After the boom had been passed all lights were extinguished and the vessels steamed to the southward under the shadow of the hills. For some distance all went well, but after a time the squadron was discovered by the enemy's torpedo-boats which made signal and gave the alarm to the blockading squadron. Fire was opened on the torpedo-boats by rifle and machine-gun fire and it is probable these would have been destroyed for they were within dangerous range. But their work as pickets had been done, for soon after the Mercury and Mariner, representing a strong blockading force, made their appearance and necessitated a return to port on the part of the vessels which had attempted to escape. Some of the torpedo-boats succeeded in getting sufficiently near to the armored vessels, while unobserved, to use their torpedoes effectively. Their great value as pickets or lookouts of a blockading force was clearly shown.

A similar attempt was made by the unarmored vessels on the night of the 15th to elude the watchfulness of the torpedo-boats. The Mariner and Racer were detected and hotly pursued, but the Mercury, from her superior speed, was successful in escaping.

On the 23d a squadron, consisting of the Repulse, Ajax, Devastation, Hercules, and Conquest, under the command of Rear-Admiral Hoskins, was detached as representing a part of the enemy's force and all communication between them and the remainder of the fleet (under the command of Rear-Admiral Whyte) ceased. (Admiral Hornby now became the umpire for the operations about to ensue.)

After the departure of the attacking squadron the double boom was reinforced by a smaller one placed about 10 feet outside the former. The squadron began to use their search lights at night.

All was now ready for the intended attack upon the fleet in Berehaven Roads, which was however delayed until the constantly postponed arrival of the expected gunboats. In the meanwhile the squadrons were exercised at general quarters during night and day, the mine field and other defenses were strengthened, and spies and reconnoitering boats and parties were sent out from either side to ascertain the other's position and arrangements.

Finally, on Saturday evening, the 27th, the long-awaited gunboats Medina, Medway, Pike, and Snap arrived. On Monday, the 29th, the vessels engaged in the defense of Berehaven took position as follows:

In the middle of the bay the Minotaur, Polyphemus, Lord Warden, Iron Duke, Sultan, Penelope, Hecla, Oregon, Seahorse, and Express; at the eastern boom the Medina, Medway, Racer, Mariner, Hotspur, and Shannon, the latter moored end on to and two cables inside the boom. Her 18-ton guns covered it and the mine field, which were further protected by land defenses manned by two hundred and fifty marines and a blue-jacket battery of three 20-pounders. The western boom was similarly protected by the Rupert, Snap, Pike, and land batteries. On Bere Island the entire force consisted of six hundred blue jackets and marines.

It was announced in the morning that the two squadrons would enter into hostilities at 2 p. m. After this the eastern obstructions were still further defended by thirty-nine boats from the ships.

The Berehaven scouts discovered the Mercury and four of the enemy's torpedo-boats at 5 p. m., and a skirmish ensued, which resulted in the capture of one torpedo-boat on each side.

The enemy's squadron, under Rear-Admiral Hoskins, was now near Glengariff, some 18 miles from Berehaven.

One umpire was appointed for each squadron, and a number of sub-umpires were detailed to accompany ships, boats, and land forces. Admiral Hornby acted as chief umpire and was to decide as to the result and time of finishing the fight. Blank ammunition was supplied for boat guns and small arms, but none for the machine guns. The following rules were to be observed:

A boat will be put out of action if it is in the beam of an electric light and is under the fire of a field or heavy gun at ranges up to 600 yards for ninety seconds, or at ranges up to 1,200 yards for two minutes. It will also be put out of action by machine-gun fire within 600 yards for two minutes, or if it passes within 30 yards of a hostile boat of superior force, or of two inferior hostile boats of equal force.

Gunboats may be put out of action by being struck by a torpedo.

The Hotspur and Rupert may be similarly disabled.

The Whiteheads will be used without explosive charges, but will carry the Holmes light which will show the direction of the weapon.

Ships put out of action will immediately extinguish their electric lights. They need not, however, recall their boats. Infantry fire is to be considered effective up to 600 yards and artillery fire up to 3,000 yards.

At 9 p. m. of the 29th the moon rose, but it was difficult to see far as a slight fog or haze hung over the water. At 10.43 the scouts signaled three ships and three torpedo-boats 6 miles east of the boom, and half an hour later they were discovered close at hand. Red lights were thrown up by one of the torpedo-boats of the defense which was the signal that the attacking force was within range. It was difficult to make out the attacking vessels from the boom. They carried no lights and were enveloped in darkness, but the search lights of the Mariner soon made visible the Mercury with a string of armed boats in tow. Fire was opened from the heavy guns of the Medina. A rush was then made by the attacking boats, supported by the fire of their ships, with the object of destroying the boom by explosives or other means, but under the glare of numerous search lights, the fire of great and machine guns and small arms, and the explosion of mines, the force was driven off. One launch succeeded in getting over the boom, but was then captured by boats. Dummy charges were placed by the attacking force at one or two places on the boom, which, had they been exploded, would have destroyed it.

A similar attack was made at the same time upon the western boom, but it also failed.

The attack lasted till 1 o'clock, when the enemy was clearly defeated. A fleet of torpedo-boats lay inside the boom ready to attack in case it should have been destroyed.

The boom and defenses having withstood the attack of boats, supported by ships, it was decided to determine its resistance to the ram. The Polyphemus was the vessel chosen to make the experiment, during which the field of mines was supposed not to exist, or to have been removed by countermining boats. But in place of these mines a number of torpedo-boats were employed to fire their torpedoes at the Polyphemus as she approached the boom. Going a mile or more outside the harbor mouth she gathered way and steamed for the boom with a speed of 17½ knots. The exploit is thus described by the London Standard:

> As she approached the obstruction she was fired at by numerous torpedoes, all of which she escaped although their aim was remarkably good.
>
> It seems to be established that the vast wave which she raises when steaming at full speed deflects these missiles from their course ere they can reach her side.* If this is so, it may be taken for granted that, in action, she would only be disabled by means of stationary mines fired either by contact or by observation. Before she smashed the boom yesterday she traversed the mine fields and in so doing she exploded three mines, any one of which in actual warfare would in all probability have inflicted upon her serious damage. I have said she escaped from all the hostile torpedoes; one of them, however, is alleged to have passed beneath her, although at too great a depth to strike her; the others were either deflected by the wave or were sighted and outmanœuvered, thanks to the excellent way in which Captain Jeffries handled his ship. Last night a slight scrape on her port quarter was the only evidence of what she had gone through.

Upon striking the boom she crushed through the obstacle (two topmasts and hawsers) as if it had been of paper, severing the two 5-inch steel wire hawsers without the slightest difficulty.

Another portion of the boom was blown up later by a 37-pound charge of gun-cotton. The spars were shattered and the two steel hawsers were clearly cut through. But the breech was not a wide one, and the damage was incomparable with that done by the Polyphemus.

After arriving at Blacksod Bay a memorandum was issued by Admiral Hornby to commanding and other officers of the fleet, calling for opinions on questions having reference to the defense of harbors and to the recent operations at Bantry Bay.

A general opinion was first asked as to the best method of preparing a rapid defense of such an anchorage as Berehaven by a squadron seeking shelter there from a superior force; second, as to the best method of defending such a harbor, leaving a comparatively small force in order to hold it as a base of operations. The following were some of the details to be considered:

(1) The general efficiency of the naval mining system for such operations.

(2) The advisability of filling observation mines with gun-cotton, instead of using sinkers.

(3) The value of the naval electro-contact mine.

(4) The efficiency of naval electro-mechanical mines and their safety in laying down and picking up.

(5) The advisability of using the same circuits for countermining and for electro-contact mines.

(6) Whether, if separate circuits were used for electric mines, it would not be advisable to lay them on a multiple cable, so that each mine could be separately tested and lifted.

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*See French manœuvres for contradictory opinion regarding this.

(7) Whether a fleet could be rendered perfectly secure against a night attack on the part of ships by means of torpedo-boats moored in suitable positions so as to act as fixed batteries and without the assistance of fixed mines. This point to be determined in the light of the experiment with the Polyphemus on the 30th of June.

(9) The value of the electric light when placed on shore or in boats away from a fleet, and the best means of so placing it.

(10) The best means of defense against an attack by fast torpedo-boats.

(11) The best means of mining defense for a fleet of ships from which all mining stores have been removed but which is accompanied by one or more Heclas. The safety and value of certain mines (Pietraski).

(12) The best form of booms for defensive purposes.

(13) Should the boom be inside or outside the mine field, or should there be two booms?

(14) Suppose the span boom is preferred, how is the necessary timber to be carried or found in a squadron of mastless ironclads?

(15) Should nets be suspended from a boom; and, if so, how should they be carried?

(16) Are boat mines, as laid out, efficient; if not, how improved, and where laid down?

(17) Should guard-boats be used; if so, where should they be placed, and how should they be armed and used?

(18) Are the operations of sweeping, creeping, and countermining the best that can be devised for clearing a passage for ships through a mine field?

(19) Method of destroying an ideal boom.

(20) The method of anchoring a fleet on the defensive in harbor.

All the spars, mines, &c., having been recovered by noon of the 2d July, signal was made to get up steam. By 6 o'clock the whole squadron was under way, and proceeded to sea in two columns, each of the torpedo-boats accompanying an armored vessel. The gunboats were taken in tow.

On the 4th the squadron anchored in Blacksod Bay, where the plan of operations included the defense of the bay by means of an extensive field of electric contact-mines, some twelve or fifteen of which were to be laid down by each ship, and other torpedo experiments.

The Whitehead practice on the 6th, when the sea was quite rough, seemed to indicate that the torpedo was not deflected or disturbed in its flight by the action of the sea. One of the torpedoes sank, on account of striking an obstacle.

On the 7th, the weather continuing bad and the sea being too heavy to admit of placing the mines as contemplated, the torpedo-boats, eight in number, were sent away under Commander Galway to attack the squadron after nightfall. It was arranged that the gunboats and corvettes, which were anchored outside and around the three central lines of armored vessels, should display their search lights in such a manner as to encircle the fleet with a band of light, outside of which armed launches and boats, in sight of each other, should be anchored to act as lookouts; and beyond these again the second-class torpedo-boats (carried by the vessels of the fleet) should patrol the outer zone. The vessels had their torpedo-nets down. A quarter watch was kept at the guns and on the lookout.

The night was fairly clear and there was a steady breeze with a choppy sea. About 11.20 the enemy was discovered to the south and the guns of the Ajax were immediately after engaged. This attack failed. In the second, while several of the torpedo-boats reached striking distance, they were in most cases put out of action by the fire of the ships before they could effectively discharge their Whiteheads. Other attacks ~~was~~ were made until the supply of torpedoes were exhausted. No ship struck by a torpedo, but torpedoes hit and were stopped by the nets of the Rupert, Hotspur, and Ajax.

On the morning of the 8th the vessels were ordered to take in their defenses.

On the morning of the 10th a squadron, under Rear-Admiral Whyte, consisting of the Agincourt, Rupert, Ajax, Hotspur, Sultan, Repulse, Penelope, Conquest, Comorant, Mariner, Medway, Snap, Oregon, and four first-class torpedo-boats, was detached. Their orders were, first, to prevent Admiral Hornby's command (the remainder of the fleet) leaving Blacksod Bay unseen; and, second, to prevent his getting to Greenock or Belfast without a fight for the passage.

To make sure of the first, the Oregon was stationed off Iniskea (one of the outlying islands) as lookout. The Conquest and torpedo-boats proceeded at full speed to Lough Swilly. The remainder of Admiral Whyte's squadron arrived at Red Bay on Saturday, the 11th.

Admiral Hornby's force was ordered to prepare for departure shortly after 10 p.m. of the 10th. It was a thick night, with rain falling in torrents, when the squadron got under way and steamed out of the bay, the Mercury acting as scout. The vessels were seen, however, by the Oregon which at once started off and reported to Admiral Whyte the fact of their departure and that one vessel (the Iron Duke) was left behind.

Admiral Hornby's squadron, unconscious of the Oregon's whereabouts, continued to the westward. Steaming into a head sea the smaller vessels experienced difficulties. The gunboats in tow of armorclads were at times almost under water, while the torpedo-boats fared badly and were obliged to make long stretches, as if beating to windward, in order to make way and weather of it. At daybreak the squadron had made an offing of 50 miles, when the admiral decided to send the torpedo-boats, under convoy of the Mariner and Hecla, into the land for shelter; at the same time he stood to the northward and eastward toward the Scotch coast. The Seahorse was disguised and sent ahead to reconnoiter.

On Monday morning, the 13th, the vessels anchored off Scalasaig, where the Mercury was waiting with the torpedo-boats. Nothing having been seen of the enemy it was supposed that he was ignorant of the movements of Admiral Hornby's vessels. The squadron accordingly weighed and steered for the Sound of Islay, arriving the next morning before daylight. Here it again anchored. A torpedo-boat went out and reported all clear, but a party of men had, from the top of a neighboring hill, discovered the Oregon and others of the enemy's scouts in the offing.

About 10 p. m. the squadron again weighed and at 10-knot speed made its advance upon the Mull of Cantyre, in double column, with five scouts ahead and on either flank.

About 1 o'clock the Mull Light was reached, at which point it would be decided whether the approach to Greenock was open or defended by the enemy's fleet. As the flagship passed the light and found its entrance unopposed it fired a rocket to indicate that the movement had been successful; but a moment later the signal was answered by two rockets from the southwest, fired by the Agincourt, which, in company with two other vessels, was steaming along the Irish coast. From this position they were unable to prevent Admiral Hornby's entering the Clyde, but finding the enemy thus close at hand, he proceeded to Belfast instead of Greenock.

While not in a position to prevent such an entry, Admiral Whyte's scouts had, however, reported to him every important movement of the opposing squadron, *whose smoke alone is said to have been sufficient to have betrayed it* from the time it left Blacksod Bay to its arrival at the Mull, but he was apparently unable to get together at the critical moment a sufficient force to fight it with any chance of success.

Opinions differed at the time as to the success of Admiral Hornby's attack, but it seems fair to believe that he could have at least carried out his intention of making a descent upon and causing the destruction of the great establishments along the Clyde, although his enemy would certainly have been upon him in force within a few hours after his work had been begun.

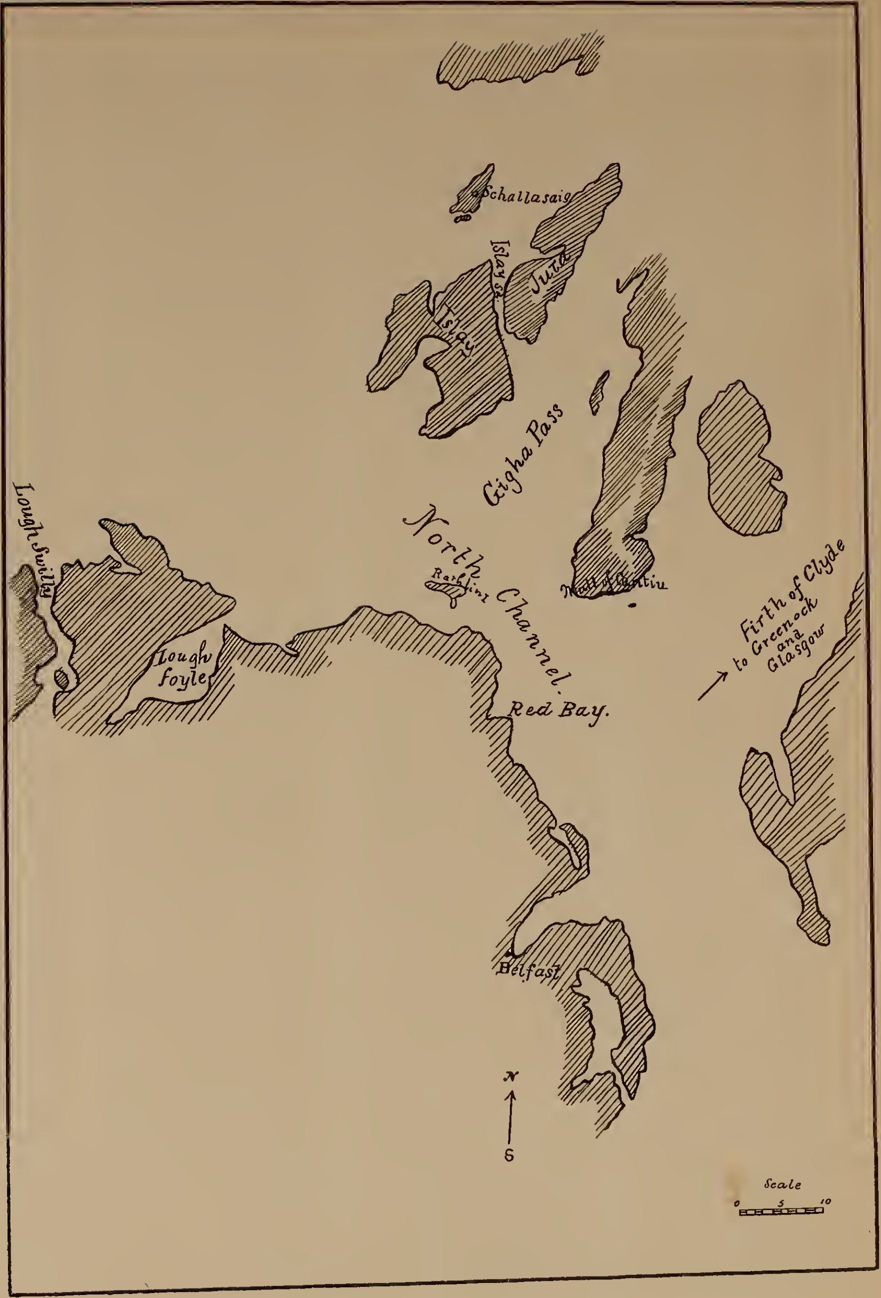
(This simulated attack upon the Clyde, an important commercial center with insufficient means of defense, may serve to illustrate the necessity of properly defending some of our great ports.)

On the 16th the squadron left Belfast and went to sea in three columns, the corvettes and sloops thrown out as scouts, the small gunboats in tow, and each of the eight torpedo-boats under the counter of an armorclad.

The next morning the gunboats were cast off and the squadron exercised at tactics, during which it was divided into two parts, each with its proper number of broadside and turret ships, &c. The divisions attacked each other twice, moving at a speed of 8 knots.

This terminated the manœuvers, and on Thursday, the 23d, the squadron proceeded to Portland, where it was dispersed.

As one of the incidents of the cruise of the particular service squadron may be mentioned the accident to the newly commissioned and recently completed Leander. The cruisers of the squadron had been outside as usual about nightfall and were returning toward 10 p. m. to their anchorage by the western entrance. In taking their berths for the night, while avoiding the Mercury and Mariner, which had just


Schallasaig
Islay Sd.
Jura
Islay
Gigha Pass
North Channel.
Rathlin
Mull of Cantire
Lough Swilly
Lough foyle
Red Bay.
Firth of Clyde
to Greenock
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anchored and were swinging across the channel, the Leander grazed along a pinnacle rock known as the Hornet, tearing an ugly rent in her port side abreast a watertight bulkhead, starting some of the plates and many rivets. She made water very rapidly, but thanks to her powerful pumps and watertight compartments was kept afloat during the night. The fire under the forward boilers was flooded almost immediately. The collision mats were quickly placed, but were too small to cover the holes. The next morning the squadron divers plugged the rivet-holes and covered the large holes with plates (lined with cotton waste and felt) intended to stop shot holes. On the inside a coffer-dam was built, and finally a large sail was secured outside the damaged part of the hull. After this the pumps began to make headway and the vessel proceeded to Plymouth. An examination in dock discovered the great (local) injuries received and proved the excellence and superiority of steel as a ship-building material.

The manœuvers, extending through a period of forty-six days, were conducted under circumstances but little removed from those of actual warfare, under the most skillful masters and tacticians of a great service, with all the appliances with which England a few weeks before was about to wage war with Russia upon the seas.

Lessons drawn from them are consequently most instructive. The story of the campaign is before the reader, who may draw his own conclusions, which may or may not differ from those here submitted.

CONCLUSIONS.

In regard to the utility of booms: However carefully constructed they may be, while impervious to the attack of torpedo or other boats, if properly defended, they offer no serious resistance to the charge of a ship moving at high speed.

A fleet at anchor should always be protected by a double or triple boom, defended by guns and mines. But as the masting of fighting ships is being reduced to a minimum, the means for constructing booms should be furnished by special supply vessels carrying spars, nets, and the necessary wire hawsers.

The Bantry Bay booms withstood a moderate gale about the 21st June, although many casks and small spars were washed away.

Blockades may still be effective if the blockading squadron is attended by numerous torpedo-boats and swift, light vessels, though the methods must necessarily be different from those employed during our war.

Torpedo-boats must be divided into two classes, those intended for limited operations upon the open sea, and those intended for harbor defense or as part of a ship's equipment. Boats of the first class, of 108 feet length and upwards, are doubtless quite safe in any ordinary weather, but smaller boats should not attempt to accompany a squadron away from the coast.

The light scantlings of which these boats are built makes it imperative that they should never be used for towing or other purposes for which they were not intended. Every precaution to prevent the deterioration of their hulls should be observed.

While the torpedo-boats accompanied this squadron in all weathers, their extreme vivacity in a sea way renders the accurate discharge of their toepedoes most uncertain, and it is believed that armored or cruising vessels, *properly defended*, have little to fear from the *small types* of boats in *bad weather*.

As for the efficiency of torpedo-boats against cruisers or vessels of high speed it is thought the large vessel also will always have the advantage. In a moderate sea the speed of the torpedo-boat falls from 20 (on trial) to 15 knots or less, and the 17 to 19 knot cruiser can run away from pursuing boats, or hold them at a distance under the fire of machine and heavy guns. It was shown that the Mercury was always superior to the attack of torpedo-boats, when the other cruisers of good speed, steaming at 12 to 13 knots, must have been easily overtaken by them.

The conclusions arrived at by the French squadron of evolutions of the previous year was, that these boats could accompany a squadron at sea in all weathers. That this is the case for a short period of time is doubtless true, but there is another side to the question. To be on board a 110-foot torpedo-boat when the sea is lively is said to be far from agreeable. The heat, noise, and vibration of the rapid engines are intense. Cooking seems to be out of the question, and it is said that if food were well cooked few would be able to appreciate it. To obtain necessary rest under these conditions, added to the rapid motions of the boat, is most difficult. The French authorities have been credited with the opinion that torpedo-boats are only habitable for expeditions of short duration, and that if the period extends beyond forty-eight hours they must of necessity suffer greatly. The experience of the particular service squadron verified this, and has induced the building of much larger boats of 125 to 150 feet in length, with displacements ranging from 80 to 150 tons.

The Hecla, torpedo depot and supply ship, fitted with machine shops and supplies for repairing and refitting torpedoes and boats, and carrying upon her rail six second-class torpedo-boats, gave general satisfaction and indicated the necessity of attaching such vessels to all squadrons.

The Polyphemus demonstrated her great handiness and speed.

The Mercury, with her high speed, proved herself a most valuable type of vessel, whether as a scout or for general service.

The Oregon, with great speed and coal endurance, was found to be of great value to the fleet as a scout and in a variety of other duties requiring dispatch.

The advantages and necessity of high speed became fully apparent and have been generally acknowledged.

The gunboats proved themselves totally unfit for service other than that of harbor defense. Of little inherent speed, when towed at the rate of 8 knots they became utterly unsafe, and gave indications that an increase of speed would cause them to founder. As harbor-defense vessels, however, they must always be valuable as floating platforms for formidable guns.

The necessity of light and swift vessels to act as scouts, to be the eyes of the fleet, as were the frigates in bygone days, was clearly demonstrated.

Coaling vessels should accompany squadrons at all times.

VESSELS COMPOSING THE PARTICULAR SERVICE SQUADRON.

ARMORED.

Minotaur.—Broadside battle ship; launched 1863; 10,690 tons; fifteen 9-inch, 12-ton M. L. R.; two 6-inch B. L.; two 20-pounder B. L.; eight 24-pounder S. B.; 14.4 knots (max. speed); I. H. P., 6,700; complement, 710.

Agincourt.—Sister ship; launched 1865.

Hercules.—Central casemate battle ship; 1868; 8,680 tons; eight 9.2-inch 18-ton B. L.; six 6-inch B. L.; six 4-inch B. L.; 14.7 knots; I. H. P., 6,750; complement, 630.

Sultan.—Central casemate battle ship; 1870; 9,290 tons; eight 9.2-inch 18-ton B. L.; four 8-inch 11-ton B. L.; seven 4-inch B. L.; 14 knots; I. H. P., 7,720; complement, 632.

Shannon.—Belted cruiser; 1875; 5,390 tons; two 10-inch 18-ton M. L. R.; seven 9-inch 12-ton M. L. R.; six 20-pounder B. L.; 12.3 knots; I. H. P., 3,540; complement, 454.

Iron Duke.—Central casemate battle and cruising ship; 1870; 6,010 tons; ten 9-inch 12-ton M. L. R.; four 5-inch B. L.; six 20-pounder B. L.; 13.4 knots; I. H. P., 4,270 complement, 490.

Lord Warden.—Broadside battle ship; 1865; 7,840 tons; two 9-inch 12-ton M. L. R.; fourteen 8-inch 9-ton M. L. R.; two 7-inch 6½-ton M. L. R.; six 20-pounder B. L.; 13.5 knots; I. H. P., 6,700; complement, 605. (Was laid down as a wooden frigate. Was stricken from the list of sea-going ships August, 1885.)

Repulse.—Broadside cruising and battle ship; 1868; 6,190 tons; twelve 8-inch 9-ton M. L. R.; six 20-pounder B. L.; 12.3 knots; I. H. P., 3,350; complement, 523. (Was laid down as a wooden line-of-battle ship. Was stricken from the list of sea-going ships August, 1885.)

Penelope.—Central casemate cruising ship; 1867; 4,470 tons; eight 8-inch 9-ton M. L. R.; three 40-pounder B. L.; two 20-pounder B. L.; 12.7 knots; I. H. P., 4,700; complement, 350.

Ajax.—Two-turret battle ship; 1880; 8,510 tons; four 12.5-inch 38-ton M. L. R.; two 6-inch B. L.; 13.5 knots; I. H. P., 6,440; complement, 385.

Devastation.—Two-turret battle ship; 1871; 9,330 tons; four 12-inch 35-ton M. L. R.; 13.8 knots; I. H. P., 6,638; complement, 358.

Hotspur.—Single turret ram; 1870; 4,010 tons; two 12-inch 25-ton M. L. R.; two 6-inch B. L.; 12.6 knots; I. H. P., 3,060; complement, 224.

Rupert.—Single turret ram; 1872; 5,440 tons; two 9.2-inch 18-ton B. L.; two 6-inch B. L.; 13.6 knots; I. H. P., 4,630; complement, 217.

Polyphemus.—Torpedo ram, armored turtle-back deck; 1881; 2,640 tons; machine and R. F. gun armament, and numerous Whitehead torpedoes; 17.8 knots; I. H. P., 5,780; complement, 132.

Each of these ships carries Whitehead torpedoes and a secondary battery of Nordenfeldt, Gardner, and rapid-firing guns.

UNARMORED.

Conquest.—Cruiser with partial protective deck; 1878; 2,380 tons; two 7-inch 4½-ton M. L. R.; twelve 64-pounder M. L. R.; 13.6 knots; I. H. P., 2,670; complement, 265.

Leander.—Cruiser with partial protective deck; 1882; 3,750 tons; ten 6-inch 89 cwt. B. L.; 16 knots; I. H. P., 4,658; complement, 257.

Mercury.—Armed dispatch cruiser; 1878; 3,730 tons; thirteen 5-inch B. L.; 18 knots; I. H. P., 7,290; complement, 257.

Cormorant.—Small cruiser; 1877; 1,130 tons; two 6-inch 81 cwt. B. L.; six 5-inch 36 cwt. B. L.; 11.6 knots; I. H. P., 950; complement, 138.

Mariner.—Cruising gun vessel; 1884; 970 tons; eight 5-inch B. L.; 11 knots; I. H. P., 970; complement, 100.

Racer.—Sister ship.

Express.—Cruising gunboat; 1874; 455 tons; two 5-inch 36 cwt. B. L.; two 4-inch B. L.; 10.2 knots; I. H. P., 450; complement, 60.

Medina.—Coast and river service gunboat; 1876; 363 tons; three 64-pounder M. L. R.; 9.5 knots; I. H. P., 310; complement, 45.

Medway.—Sister ship.

Snap.—*Staunch* type coast defense gunboat; 1872; 254 tons; one 10-inch 18-ton M. L. R.; 8.5 knots; I. H. P., 250; complement, 25.

Pike.—Sister ship.

Seahorse.—Sea-going tug; 1880; 670 tons; one 12-pounder S. B.; 12.6 knots; I. H. P., 1,472; complement, 50.

Oregon.—"Admiralty cruiser," chartered from Cunard Steamship Company, and armed for special service; 1883; 12,500 tons; six 64-pounder M. L. R.; four 5-inch B. L.; 18.2 knots; I. H. P., 13,500; complement, 317. (Sunk in collision off coast of Long Island, March 14, 1886, after having been returned to owners and re-employed in regular trade.)

Hecla.—Torpedo depot and transport ship; purchased 1878; 6,400 tons; five 64-pounder M. L. R.; one 40-pounder B. L., and numerous Whitehead torpedoes; 13.2 knots; I. H. P., 2,265; complement, 246.

Each of these ships carries a secondary battery of Nordenfeldt, Gardner, and boat guns. The *Conquest*, *Leander*, and *Mercury* carry Whitehead torpedoes.

The torpedo boats are described on page 5.

FRANCE.

The French manœuvres have this year been conducted on a larger scale than usual. The principle in naval warfare which they are intended to settle, if possible, is that of the efficiency of swift unarmored cruisers, torpedo-vessels and torpedo-boats against squadrons of heavy armored ships. Admiral Aube, the new minister of marine, who may be regarded as the professional exponent of the swift cruiser, torpedo-boat and torpedo, as Gabriel Charmes was their amateur apostle, has also enunciated doctrines of warfare which would employ these vessels beyond their past sphere—to make descents upon rich but unfortified towns, lay them under tribute or ashes and withdraw; and to make the torpedo-boat and torpedo the principal feature in sea-coast defense. As a practical expression of opinion the minister has stopped the construction of two large armored French vessels, the Brennus and Charles Martel, and has ordered in their stead a number of swift cruisers of about 2,000 tons displacement, to have a maximum speed of about 19 knots. Twenty-one new first-class torpedo-boats have also been ordered since Admiral Aube became minister.

The torpedo boat has undoubtedly assumed an important position among the fighting forces of the sea, but its rôle is not so universal as the torpedoists would have us believe. Its field of action must be restricted to short distances from its base; it cannot keep the sea for more than three or four days in bad-weather; the boat is seaworthy and has ample means for making long voyages under steam, but man, unfortunately, as a rule, is not as developed as it, and without long and special training it is not easy to find men who can withstand the great discomfort and nervous strain attending a moderately long voyage on the open sea in a 115-foot torpedo-boat under steam.

As a preliminary to the manœuvres in squadron, some eighteen first-class torpedo-boats were sent from the Atlantic ports to Toulon in order to test their sea-going qualities, as well as to re-enforce the Mediterranean torpedo flotilla. These boats crossed the Bay of Biscay during the storniest season of the year and encountered much bad weather. As their performance under such circumstances is most interesting and instructive as to their ability to cruise with squadrons at sea, a brief synopsis of some of the voyages is here given:*

No. 61 (111.5 feet long; built by Normand).—Left Brest 2d February: anchored same day at Douarnnez on account of bad weather; then proceeded along coast, stopping at Rochefort during the 6th; stopped at Ferrol, 9th to 11th; Lisbon, 12th to 17th; Malaga, 18th to 20th, Valencia, 21st to 23d; arrived at Toulon February 24, Length of voyage, twenty-two days.

A gale from the NE., with a heavy sea, was experienced off Ferrol; very bad weather during the entire passage through the Atlantic. The boat steered and behaved well and took but little water on board. The crew (nineteen, all told,) was well trained before starting.

No. 66 (first class, 108 by 10.8 by 6.5 feet, draught; 50 tons displacement).—Left Cherbourg the 3d February; anchored at Morlaix the 4th, at Brest the 6th, at Ferrol the 9th, at Lisbon the 11th, at Oran the 14th, at Port Vendres the 17th, at Marseilles the 20th; arrived at Toulon the 21st February. Length of voyage, eighteen days.

Fine and bad weather were experienced. The crew was good, but all the men were sea-sick. The commanding officer is of the opinion that the longest time which such a boat can keep the sea is *three* days.

No. 69 (first class, 49 tons).—Left L'Orient the 21st January; anchored at Corunna the 23d, Vigo the 26th, Lisbon the 28th, Malaga the 4th February, Almeria the 6th, Carthagena the 8th, Port Vendres the 12th; arrived at Toulon the 14th February. Length of voyage, twenty-one days.

The crew was an average one. The men suffered from sea-sickness and loss of sleep; the voyage was uncomfortable and the men much fatigued upon their arrival at Toulon. The commanding officer is of opinion that after *forty eight hours* of bad weather life on board a torpedo-boat becomes insupportable.

No. 70 (first class, 49 tons).—Left Cherbourg 3d February; stopped at Brest the 4th, Rochefort the 8th, Ferrol the 11th, Lisbon the 14th, Almeria, the 19th, Barcelona the 22d, Port Vendres the 23d, Ciotat the 24th, and arrived at Toulon on the same day, 24th February. Length of voyage, twenty-one days.

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* Extracts from Le Yacht and Revue Maritime et Coloniale.

The crew, above the average, had received but little training. The voyage was severe and trying, particularly in the Bay of Biscay; cooking was done with difficulty, and the men slept but little. The commanding officer is of the opinion that *three days* of bad weather is the maximum which can be endured. The crew was worn out upon arriving at Toulon.

No. 71 (first class, 46 tons).—Left Cherbourg the 3d February; stopped at Brest the 4th, Rocherort the 8th, Ferrol the 11th, Lisbon the 14th, Almeria the 19th, Rosas the 22d; arrived at Toulon the 23d. Length of voyage, twenty days.

The crew was an average one; suffered from sea-sickness; cooking was rarely feasible. The seaworthiness of the boat was established in the heavy sea off the Gulf of Rosas.

No. 72 (first class).—Left Cherbourg the 3d February; stopped at Trégnier, Brest, L'Orient, Ferrol, Lisbon, Almeria, Barcelona, and arrived at Toulon on the 24th. Length of voyage, twenty-one days.

An average crew; suffered from sea-sickness and was deprived of much sleep. Variable weather. Crew much worn out at end of voyage.

No. 74 (first class).—Left Rochefort the 22d January. After stopping at Rochefort, Ferrol, Vigo, Lisbon, Alicante, Barcelona, and Port Vendres arrived at Toulon on the 11th February. Length of voyage, twenty days.

Fair weather. A good crew; slept ill; was somewhat fatigued, but ready to proceed on arriving at Toulon. This boat made, without stopping, the distance, 600 miles, between Lisbon and Alicante, at 12 knots speed.

All the boats arrived at Toulon without injury and were not in need of repairs, except in cases of leaking boiler tubes and other trifling injuries.

The most remarkable voyage made by any torpedo-boat was that of No. 67 (first class, 47 tons displacement). This boat made the passage from Cherbourg to Toulon in eleven days, stopping a Ferrol, Lisbon, and Almeria, at average speeds varying from 11 to 14 knots.* (The officer in command has been officially commended for his quick passage.)

This officer reports his boat as habitable, though somewhat damp and sensitive to changes of temperature; that the cooking was sufficiently good; that the compass and chronometers gave satisfactory indications, although the latter suffered considerable change of rate, and that the machinery performed well during the voyage. He calls attention to the difficulty of proceeding at sufficiently low speed in a heavy sea and states that even at less than 8 knots' speed part of the boat was covered with the seas, and so uneasy as to cause racing of the engines. The crew did not suffer from the voyage, but they were trained men, having formed part of the *défense mobile* of Brest.

A leg-of-mutton sail is recommended to assist the boat in lying-to.

Lieut. E. Weyl, a clever writer on naval questions, in Le Yacht, March 3, makes the following interesting remarks:

> It is noticeable that the boats made frequent stops, which demonstrates that their field of usefulness is limited by coal and water supply and that they never can be considered as cruisers (which already needed no further demonstration).
>
> It is not thought that the habitability of boats of 50 tons can be much improved. In bad weather they are so knocked about that rest is impossible. Men sleep but little, and the bad sleeping and cooking qualities of these boats must be considered as

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* The trial speed of all these boats varied from 20 to 21 knots. Their complement is nineteen, all told.

points of weakness. It is to be remarked that the torpedo-boats in reality made but an ordinary coasting voyage, being but little out of sight of land, stopping frequently, and making for the voyage (including stops) but 4 to 4.5 knots as an average speed, although No. 74 made one stretch of 600 miles at 12 knots mean speed. We may conclude, then, that the present first-class torpedo-boat is fitted only for coast defense.

The fatigue experienced by the crews of these boats during this voyage demonstrates the necessity of selecting a special class of men for this service, and of training them to the conditions which are peculiar to it.

The scheme of operations, as indicated by the French journals, embraces tactical evolutions by the squadron accompanied by a flotilla of some thirty first and second class torpedo boats, experiments to test the efficiency of torpedoes and torpedo nets, and a determination of the relative value of torpedo boat and cruiser against armor-clads, with a view to reforming the French naval policy.

The scheme also contemplates the blockade and attack in force upon one of the French ports, the landing of the naval brigade, and experiments with torpedoes and explosives on shore.

On the 2d of March, the Amiral Duperré and torpedo-boats 58 and 59 (61 feet long, 11 tons, second class) and 63 and 64 (108 feet long, first class) engaged in torpedo practice. The first experiment was made by the Duperré, passing at full speed across the fire of 58 and 59. The boats were stationary and held in position by three cables. As the Duperré crossed their line of fire at a speed of 14 to 14½ knots six torpedoes were discharged at different angles to her course, and it is reported that all hit the ship and exploded their fuzes.

In the second experiment both boats and ship were under way. No. 58 and the Duperré approached each other, bows on, at a combined speed of about 23 knots. At a distance of 450 metres the boat fired its torpedo, which struck the Duperré 11 metres abaft the spur and exploded its fuze.

Nos. 63 and 64 each fired a torpedo under similar circumstances. The speed of the boats was 12 knots, while that of the Duperré was 14. The torpedo of No. 63 struck, though it is doubtful if it would have exploded its charge. No. 64 failed to hit the ship.

The Temps states:

> From the Amiral Duperré it was observed that in these shots the trajectory of the submarine machine underwent no deviation on approaching the iron-clad. The wave of water formed in front of a great ship at full speed has then no effect on the direction of the torpedo encountering it. Consequently it may be held as established that the English experiment at Bantry Bay is valueless, whether owing to the facts not being well understood or to the English torpedoes being badly equipped or unskillfully worked. Contrary to what has been stated on the other side of the channel, a large vessel cannot rely on the displacement of the water caused by its advance to change the direction of the torpedo.

On the 3d March, in Hyères Roads, the Amiral Duperré simulated an attack with the aid of torpedoes against an enemy's ship, represented by a floating target, towed by the Robuste. After firing torpedoes at this target (the result of the firing is not known), torpedo boats 58 and

59 made an attack upon the Duperré, which opened a heavy cannonade upon them. The boats approached within torpedo range and fired at the ship. One of the torpedoes thus fired gave evidence of having struck its mark.

The Temps says:

> The trials of the 2d and 3d March show that a torpedo well directed and properly discharged at a distance of 400 or 500 metres against a vessel proceeding at the rate of 15 knots will certainly hit it under ordinary conditions, whether directed against its bow or sides.

The old armored ship Armide, now condemned, was placed at the disposal of squadron for torpedo and target practice.

On the 24th March she was towed to the Golfe Juan, and having been cast adrift, the Colbert, Amiral Duperré, Friedland, Dévastastion, Redoubtable, and Suffren engaged in firing at her during a part of the day with their 14, 24, 27, and 32 centimetres guns, at ranges varying from 3,000 to 5,000 metres. The squadron during the practice steamed in column of vessels, and first fired the main deck guns at 3,000 metres' range, and afterward the heavier barbette guns at 5,000 metres.

The target offered by the Armide's port broadside was about 230 feet long, with a height of about 23 feet.

The results were as follows: Twenty-nine projectiles struck the armored belt, 4 of which, being of heavy calibre, perforated it, and 25 shots from the 14 centimetre guns struck the wood sheathing which had formerly separated the armor from the copper. The four heavy projectiles crushed the ship's side. One of the holes made by a 34-centimetre projectile exposed a surface of about 20 square feet; 84 holes were counted in the upper works; 27 shells passed through the ship's side without exploding. Out of 615 shots fired, there were at least 140 hits, or 22 per centum of the whole number fired. Beyond the limits of the armored citadel the ship would have been uninhabitable, for the sides, bridge, armored conning tower, and the port barbette tower were completely riddled.

All the projectiles used, with the exception of one round from a heavy gun, were of cast-iron, which accounts for the lack of penetration of most shots striking the water line armor belt (5 to 6 inches, iron).

Considering the range (3,000 to 5,000 metres), and the fact that the vessels engaged were under way, the firing must be considered as excellent. The ordnance-equipment and ammunition is said to have been very satisfactory.

The Armide was towed into Toulon after the more serious wounds had with some difficulty been patched. It is probable that she would have sunk during the exercise had not the holds been filled with empty barrels to prevent such an accident.

Exercises at torpedo firing against moving objects, practice with the Hotchkiss revolver-cannon from vessels under way, and searching with the electric search-lights were continued by the squadron.

About the middle of April a portion of the torpedo-boats left Toulon

NOTE.—For continuation of the narrative see addendum.

in company with the Fulminant and Aréthuse. After different exercises, the Fulminant was sent 6 or 7 miles ahead of the Aréthuse, near which were the torpedo-boats in groups of fours. After dark one group was sent to find the Fulminant, but failed to do so. The second group was then sent forward and after several hours the armor-clad was found by one of the boats. The night was dark, the weather bad, and rainy, and the sea heavy, which made the circumstances of the search difficult. The Fulminant, however, did not mask her lights on this occasion.

This short cruise of twenty-seven hours, in an ugly sea off Toulon, is reported by the correspondent of Le Yacht, or Journal de la Marine, to have completely used up the crews of the torpedo-boats.

[Unfortunately upon going to press information concerning the further manœuvres of this squadron has not been received. An addendum to this article will be made if possible before the number is issued.]

VESSELS TAKING PART IN THE FRENCH NAVAL MANŒUVRES.

ARMORED.

Colbert.—Armored battle-ship; launched, 1875; displacement, 8,457 tons; battery, eight 10⅝-inch B. L., two 9.5-inch B. L., and six 5.51-inch B. L.; maximum speed, 14.5 knots; I. H. P., 4,650; complement, 702.

Amiral Duperré.—Armored battle-ship; launched, 1879; displacement, 10,487 tons; battery, four 13.4-inch B. L. and fourteen 5.51-inch B. L.; maximum speed, 14.5 knots; I. H. P., 8,010; complement, 850.

Friedland.—Armored battle-ship; launched, 1873; displacement, 8,540 tons; battery, eight 10⅝-inch B. L. and eight 5.51-inch B. L.; maximum speed, 13.3 knots; I. H. P., 4,428; complement, 700.

Dévastation.—Armored battle-ship; launched, 1879; displacement, 9,639 tons; battery, four 13.4-inch B. L., four 10⅝-inch B. L., and six 5.51-inch B. L.; maximum speed, 15.2 knots; I. H. P., 8,000; complement, 600.

Redoubtable.—Armored battle-ship; launched, 1876; displacement, 8,858 tons; battery, eight 10⅝-inch B. L. and six 5.51-inch B. L.; maximum speed, 14.7 knots; I. H. P., 6,071: complement, 700.

Suffren.—Armored battle-ship; launched, 1870; displacement, 7,604 tons; battery, four 10⅝-inch B. L., four 9.5-inch B. L., and six 5.51-inch B. L.; maximum speed, 14.3 knots: I. H. P., 4,181; complement, 778.

Fulminant.—Armored battle-ship; launched, 1877; displacement, 5,580 tons; battery, two 10⅝-inch B. L. and four 4¾-inch B. L.; maximum speed, 13.2 knots; I. H. P., 3,550; complement, 190.

Marengo.—Armored battle-ship; launched, 1869; displacement, 7,187 tons; battery, four 10⅝-inch B. L., four 9.5-inch B. L., and seven 5.51-inch B. L.; maximum speed, 13.5 knots; I. H. P., 3,673; complement, 750.

Vauban.—Armored cruiser; launched, 1879; displacement, 5,869 tons; battery, four 9.5-inch B. L., one 7.5-inch B. L., six 5.51-inch B. L.; maximum speed, 14.32 knots; I. H. P., 4,475; complement, 450.

UNARMORED.

Aréthuse.—Double-decked barbette cruiser; launched, 1882; displacement, 3,360 tons; battery, four 6.3-inch B. L. and twenty-three 5.51-inch B. L.; maximum speed, 16 knots; I. H. P., 4,200; complement, 450.

Milan.—Dispatch vessel and rapid cruiser; launched, 1884; displacement, 1,550 tons; battery, five 3.94-inch B. L.; maximum speed, 18.4 knots; I. H. P., 4,132; complement, 150.

Dupetit-Thouars.—Light barbette cruiser; launched, 1874; displacement, 1,931 tons; battery, ten 5.51-inch B. L.; maximum speed, 15 knots; I. H. P., 2,018; complement, 206.

Desaix.—Single-decked barbette cruiser; launched, 1866; displacement, 1,683 tons; battery, four 3.94-inch B. L.; maximum speed, 14.21 knots; I. H. P., 1,442; complement, 159.

Couleuvrine.—Torpedo dispatch vessel; launched, 1885; displacement, 320 tons; battery, two 3.54-inch B. L. and three H. R. C.*; two under-water launching-tubes; maximum speed, 18 knots; I. H. P., 1,800; complement, 77.

All French vessels carry powerful secondary batteries of H. R. C. and R. F. G.

ITALY.

[Taken chiefly from Le Yacht.]

In the latter part of October the Italian fleet held a series of grand manœuvres, which terminated in the attack of a blockaded squadron by a superior force. The manœuvres were in charge of Vice-Admiral St. Bon, minister of marine.

The following ships formed the fleet of evolutions:

Eastern squadron.—Armored ships Principe Amadeo (Rear-Admiral Civita) and Castelfidardo; cruiser Amerigo Vespucci; dispatch-boat Vedetta, and four torpedo-boats.

Western squadron.—First division: Armored vessels Dandolo (Vice-Admiral Martini) and Duilio; cruiser Giovanni Bausan, and dispatch-boat Colonna. Second division: Armored ships Roma (Rear-Admiral Bertelli) and Affondatore; steam water-boat Verde, and five torpedo-boats.

The theme adopted was as follows: War having been declared, the western squadron was to follow up a squadron, that of the east, inferior in force, which was to take refuge in one of the friendly anchorages north of Sardinia. The assailants were to try to destroy this squadron, while it would endeavor to force the blockade and get to sea. The theater of operations was chosen in the group of islands at the north of Sardinia, from Cape Ferro to La Vezzi Islands, belonging to Corsica. There, at the exit of the Straits of Bonifacio, when coming from the west, the islands of Razzoli, Budelli, Maddalena, and Caprera form an archipelago, separated from the extremity of Sardinia by narrow passages.

From the fine anchorage of Maddalena, the central point of the defense, the eastern squadron kept a vigilant lookout to seaward from its torpedo-boats and by signalmen on the neighboring islands.

On the 15th of October hostilities commenced. The western squadron left Cagliari and steamed up the eastern coast of Sardinia, the Giovanni Bausan and the dispatch-boat Colonna being the scouts. The torpedo-boats, with fires lighted, were towed by the larger vessels.

Abreast of Tavolara, on the morning of the 17th, before day, the squadron headed for the Biscia passage, between Cape Ferro and the island of the same name, cast off the torpedo-boats, threw forward the

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*H. R. C.—Hotchkiss Revolving Cannon.
R. F. G.—Rapid Firing Guns.

two scouts, and detached several vessels to cut the telegraph cable from Sardinia to Italy at the Gulf of Marinella.

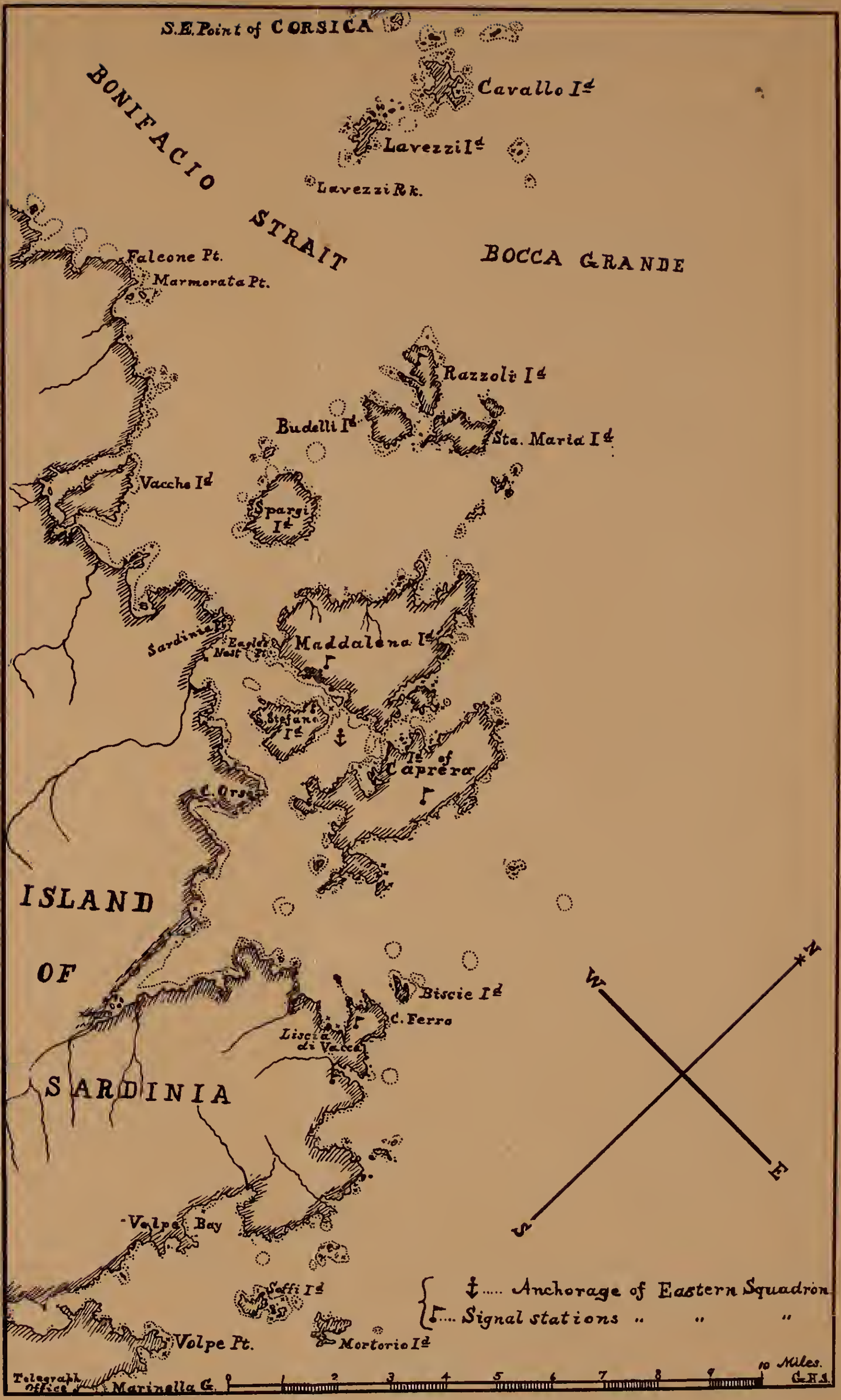
About daybreak the Bausan signaled two enemy's torpedo-boats, discovered by the electric light, which seemed inclined to observe the strength of the squadron. The Colonna sighted them at about a mile's distance and sheered off immediately; but as it was estimated that the torpedo-boats would have been a good quarter of an hour under the the machine-gun fire before being able to launch their torpedoes, had they attempted to attack the Colonna, they hastened to regain the anchorage, passing by the Biscia Channel. At the same time the division which had been anchored at Maddalena for the past two weeks was warned by the lookouts of the enemy's approach. Before attempting the attack the assailing squadron deemed it wise to provide a base of operations. To this end it selected the port of Liscia di Vacca, a little to the west of Cape Ferro, and very close to the enemy's line of defense. Before venturing into the port, the admiral got out the Duilio's second-class torpedo-boats and the steam launches, to explore the bays, to form his scouting line, and to watch the enemy's movements. At night the picket lines were formed; a squadron of first-class torpedo-boats at the western limits of Maddalena Bay, a second between Razzoli and Caprera, and the torpedo-boats of the Duilio watched the passages between Caprera and Biscia. The sea was comparatively calm. Outside, at the west entrance of the Straits of Bonifacio, were the Duilio and Affondatore; at the eastern entrance, the Dandolo and Bausan.

The Roma remained south of Cape Ferro, at Volpe Bay, to guard the *matériel* landed, and to prepare two expeditions, which the Colonna was to convoy after nightfall, with the object of reconnoitering carefully the line of obstructions and the defenses of the eastern squadron. One of these detachments returned at daylight, the other fell into the enemy's hands; but the first brought back important information on the position of the enemy and the defenses. From this detachment, as well as from captured fishermen, it was known that the passage of Biscia and that between Caprera and the coast were unobstructed by submarine mines; the squadron could therefore advance without danger and anchor at Liscia di Vacca. At daylight on the 19th this was done; the Roma, Bausan, and Affondatore moving in column, covered by the Dandolo, which was ready to receive any attack. Happily for the assailing squadron, the blockaded ships had at their disposal but a small number of torpedo-boats, for the vessels composing it had no torpedo-nets and would have been in danger in the open roadstead, chosen as a base, had an attack by torpedo-boats been practicable. The weather, which had been fine since the commencement of operations, changed during the evening of the 19th. The wind came in from the southwest with violent squalls. This did not prevent the torpedo-boats and ships' boats of the western squadron from making an attempt to force the obstructions of Maddalena Bay, but at less than a mile from the enemy's outposts the bad weather and ugly sea forced them to return. The next day there was a similar attempt, with the same result. The attempts made to surprise the enemy from the east were equally ineffectual; in the opinion of the umpires, several of the boats would have been destroyed or captured. On the San Stefano side the blockaders were not inactive, and by a stratagem they put the Castelfidardo out of action in the following manner:

A fishing-boat was seized, and two torpedomen, dressed as fishermen, were put on board with a torpedo. The boat was then sent to the Bay of Maddalena, where all day long the fishermen cast their lines. At night they got under way without arousing suspicion, advanced as far as the Principe Amadeo, failed in their attempt to discharge the torpedo, and continued to the Castelfidardo, when the explosion took place. It is certain that in time of war no one would be caught in such a trap; nevertheless it must always be borne in mind that the most minute precautions will always be indispensable. to foil similar attempts of an intelligent and ingenious enemy.

The situation of the two forces was now modified; the blockaded squadron had lost a large ship, and on the side of the assailants the greater part of the torpedo-boats were disabled. It was indispensable to hasten matters and bring the affair to a conclusion. The commander-in-chief of the western squadron then decided to attempt to capture the blockaded force by a general attack with his large vessels. As the enemy was known to be protected by lines of torpedoes, he made the following dispositions: The water-boat Verde was to be sacrificed to open the way for the iron-clads, but in order to alter her appearance she was sparred and equipped so as to resemble a large ship. She was surrounded by torpedo-nets, 8 metres deep, held in position at a distance of 15 metres from the sides by booms. At the head of the column the Verde was to explode torpedoes at the point selected for forcing the line, and open a channel for the large vessels to enter. The Dandolo and Duilio, supporting this movement with their artillery, were to follow close in succession.

Chance, however, decided otherwise. While the blockading squadron was preparing for this attempt, the eastern squadron made arrangements to force the blockade and try to escape. At 10 p. m., at the time the Verde was to start, the Vedetta with three torpedo-boats, followed by the Principe Amadeo, entered the channel to pass between Sardinia Point and the Eagle's Nest. The night was dark, with a strong wind blowing. Soon a torpedo-boat discovered the escaping squadron, but as the boat was within the range of the Hotchkiss guns, it was considered out of action. A few minutes later the Amadeo, continuing west at full speed, was seen by the picket-boats of the Duilio. The latter opened fire at 2,000 metres and obliged the Amadeo to surrender. (?) A little later the Vedetta met the same fate. There was no decision regarding the torpedo-boats of the Maddalena squadron, for the umpires


S.E. Point of CORSICA
BONIFACIO
STRAIT
Cavallo Id
Lavezzi Id
Lavezzi Rk.
BOCCA GRANDE
Falcone Pt.
Marmorata Pt.
Razzoli Id
Budelli Id
Sta. Maria Id
Vacche Id
Spargi Id
Maddalena Id
Sardinia Pt.
Eagle's Nest Pt.
S. Stefano Id
Id of Caprera
C. Orso
ISLAND
OF
SARDINIA
Biscie Id
C. Ferro
Liscia di Vacca
Volpe Bay
Soffi Id
Mortorio Id
Volpe Pt.
Telegraph Office
Marinella G.
W
N
E
S
⚓ .... Anchorage of Eastern Squadron
⚑ .... Signal stations " " "
0
1
2
3
4
5
6
7
8
9
10 Miles.
G.H.S.

could not agree as to whether they would have been able to discharge their torpedoes before being sunk.

The manœuvres here terminated. There were no torpedo experiments, nor were the vessels supplied with nets for torpedo defense. (Previous to these manœuvres experiments against torpedo-nets had been made in Italy, when it was shown that the steel-wire nets gave satisfactory results, and though dragged some 7 or 8 feet by the torpedo, it effectually stops this weapon beyond the limit in which its explosion is dangerous to a vessel.) The conditions under which the fleet was manœuvred were strictly those which war imposes. No accidents occurred, and operations were carried on by night and day, in bad weather as well as good.

No boom was used to protect the blockaded squadron from attack, nor did the attacking force protect its base by any such contrivance.

The Italians are said to have formed the opinion during these manœuvres that they have not a sufficient number of rapid cruisers and torpedo-boats, and their naval estimates for the coming year are so framed as to overcome this weakness.

VESSELS TAKING PART IN THE ITALIAN MANŒUVRES.

ARMORED.

Duilio.—Turret battle-ship; launched, 1876; displacement, 11,438 tons; armament, four 17.72-inch 100-ton M. L. Armstrong, in pairs in two turrets; maximum speed, 15 knots; I. H. P., 7,710; complement, 431.

Dandolo.—Sister ship to Duilio.

Principe Amadeo.—Cruising broadside armor-clad; launched, 1872; displacement, 5,974 tons; armament, one 11-inch 25-ton M. L. R. Armstrong on forecastle, with bow fire: six 9.84-inch 18-ton M. L. R. in two armored casemates: maximum speed, 12.4 knots; I. H. P., 3,413; complement, 523.

Castelfidardo.—Cruising broadside armor-clad; launched, 1863; displacement, 4,259 tons; armament, two 8.66-inch M. L. R. 12-ton Armstrong in armored casemate; nine 7.87-inch M. L. R. 9-ton Armstrong, of which six are in armored casemate, two on forecastle, and one in stern; maximum speed, 12 knots; I. H. P., 2,125; complement, 457.

Roma.—Cruising broadside armor-clad; launched, 1863; displacement, 5,458 tons; armament, eleven 8.66-inch M. L. R. 12-ton Armstrong, ten of which are in armored casemate and one in bow; maximum speed, 13 knots; I. H. P., 2,919; complement, 523.

Affondatore.—Double-turret armor-clad; launched, 1865; displacement, 4,062 tons; armament, two 9:84-inch B. L. in turrets, one in each; maximum speed 13 knots; I. H. P., 3,240; complement 261.

UNARMORED.

Giovanni Bausan.—Protected cruiser; launched, 1884; displacement, 3,068 tons; armament, two 10-inch B. L. 25-ton Armstrong in barbettes, one forward, one aft; six 6-inch B. L. 4-ton Armstrong in broadside on sponsons; maximum speed, 17.5 knots; I. H. P., 6,680; complement, 241.

Amerigo Vespucci.—Second-class cruiser; launched, 1882; displacement, 2,533 tons; armament, eight 5.91-inch B. L. in broadside; maximum speed, 15 knots; I. H. P., 5,000; complement, 300.

Marc Antonio Colonna.—Gun vessel and dispatch boat; launched, 1879; displacement, 656 tons; armament, two 4.72-inch B. L., five 3-inch B. L.; maximum speed, 15.9 knots; I. H. P., 1,700; complement, 104.

Vedetta.—Gun vessel; launched, 1866; displacement, 827 tons; armament, four 4.72-inch B. L.; maximum speed, 11 knots; I. H. P., 661; complement, 95.

Verde—Steam water boat; displacement, 470 tons; no armament; horse-power, 154; complement, 37.

The torpedo boats were 100 feet long, and of 35 to 40 tons displacement.

GERMANY.

The German naval manœuvres embrace several valuable principles of instruction and preparation: to test the facilities for the mobilization of the fleet; to ascertain the condition of ships and their equipment, of fortification and armament, torpedo-boats, torpedoes, mines, and the apparatus used in connection with these; to instruct officers and men in the art of tactics and naval warfare, and to familiarize the former with the nation's coasts and the defenses of its naval and commercial ports.

The manœuvres of 1885 were divided into two principal periods, the first near Wilhelmshaven and the second off Kiel.

(1) Operations near Wilhelmshaven.

The theme adopted consisted in an attack in force upon Wilhelmshaven, of which the entry was defended by a line of mines, the forts on the Jahde, and a squadron with torpedo-boats. Thirty-four vessels of all classes took part on both sides in the manœuvres.

The attacking squadron, commanded by Rear-Admiral von Blanc, was composed of the following vessels: Stein, cruiser (flag-ship); Friedrich-Karl, armored broadside ship; Baiern and Hansa, armored ships; Olga, Nymphe, and Sophia, cruisers; Pfeil and Brummer, dispatch vessels; and nine torpedo-boats (8 of the Vulcan type and 1 Thornycroft).

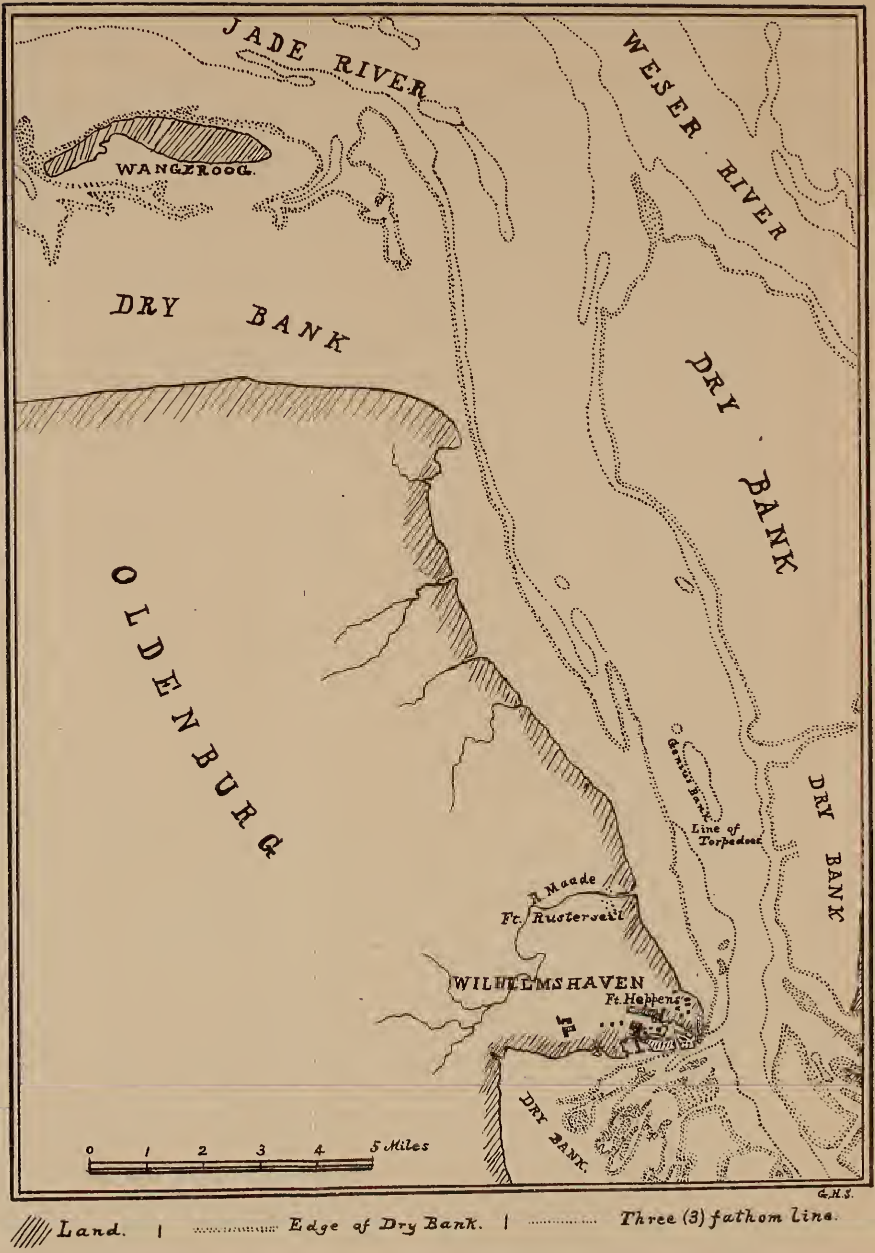
The defending squadron was composed of Moltke, cruiser; Wespe, Mücke, Viper, and Salamander, armored gun-boats; Blitz and Pomerania (flag-ship), dispatch vessels; Norder and Zephir, armed harbor vessels; and six torpedo-boats (Schichau type).

A number of launches and small vessels also took part in the operations.

The forts Rustersiel and Happens and other batteries were manned. A line of torpedoes was placed in front of Fort Rustersiel; all buoys and beacons marking the entrance to the Jahde were removed as in time of war, and the lights along the coast extinguished during the manœuvres.

The attacking squadron left Wilhelmshaven on the 31st, at 5 a. m., and went to sea to commence operations.

At 3 p. m. the Semaphore at Wangeroog, at the mouth of the river, signaled the enemy in sight. The defending squadron at once weighed and went outside to offer battle.


JADE RIVER
WESER RIVER
WANGEROOG
DRY BANK
DRY BANK
DRY BANK
DRY BANK
OLDENBURG
Genius Bank
Line of Torpedoes
R. Maade
Ft. Rustersiel
WILHELMSHAVEN
Ft. Heppens
0 1 2 3 4 5 Miles
G.H.S.
Land. | Edge of Dry Bank. | Three (3) fathom line.

The Friedrich Karl, being much in advance of her consorts, became engaged, and succumbed to the attack of the Moltke and four torpedo boats. In spite of this loss, however, the squadron under Admiral von Blanc drove the defending vessels back and caused them to take shelter in the Jahde, with an additional loss of the Norder, Zephir, four steam launches, and a mine-laying boat.

The attacking squadron then anchored in front of the line of mines, and, night falling, began to drag the mine-field to open a passage to the harbor. The defense brought all its efforts to defend these obstructions, and the vessels, re-enforced by the Friedrich-Karl (previously captured, but released), opened upon the boats with a hot fire from the Hotchkiss guns. The attacking squadron assisted its boats as far as possible, and threw its electric lights upon the supposed position of the mines; an expedient much criticised, as it allowed the enemy to correct his fire. Four torpedo-boats were now thrown forward to harass the defending squadron. One of them succeeded in crossing the mine-field, and, without being seen, arrived within range of the Blitz, which could have been easily sunk. The torpedo-boats of the defense made a sortie close under the land, and attempted to attack Admiral von Blanc's vessel from seaward. Although the night was very dark, they were detected by the aid of the search lights and nearly all put *hors de combat.* One of these, however, succeeded in sinking (?) the Hansa.

Shortly after this incident the defending squadron shifted its anchorage, and, the moon rising, hostilities were suspended until 7 o'clock the following morning, when they were recommenced by an attack of torpedo boats, which, being subjected to a heavy fire of machine and other guns, was unsuccessful; the boats being captured, sunk, or driven back. The squadron then withdrew to the Genius bank. On the 2d, at 5 p. m., the assailants having presumably succeeded in opening a passage through the line of mines, prepared to advance in single column upon the vessels of the opposing squadron, but these, being assisted by the fire of the forts, poured upon the advancing squadron such a storm of imaginary missiles that it was obliged to give up the attempt to enter the harbor, and after engaging the forts by presenting to them the broadsides of the fleet, it covered its retreat by again sending foward its fleet of torpedo boats, which were also driven off. The squadron then retired at 7 p. m. to the Genius bank, and the manœuvres were brought to a close.

The chief lessons these manœuvres seem to teach are that torpedo-boat attacks in the daytime are doomed to failure, and that the electric light may in cases prove of greater advantage to the enemy than to those using it; that the defenses of Wilhemshaven by land and water render a sea attack impracticable or only possible at enormous loss. It is stated that the German idea of the use of torpedo boats accompanying a fleet in order of battle is that they shall operate from and near its flanks so as to be in position to take advantage of opportunities afforded by the smoke to attack the enemy, and, if possible, from the rear.

(2) OPERATIONS NEAR KIEL.

The scene of operations was now transferred to Kiel, the naval stronghold on the Baltic. The scheme adopted was similar to that employed at Wilhelmshaven.

The defense occupied Forts Falkenstein and Stosch with marines and naval artillery (seamen), which were placed in electric communication with each other and other military posts. A detachment of marines (sea battalion) of the dock-yard division also garrisoned Laboe.

Operations began on the 16th September. Mines were placed by lighters on the 16th, and electric lighting apparatus and signal stations established on both sides of the entrance. The defending squadron left the harbor on the 16th: composed of the Ariadne, Nymphe, Blücher, and Rover, cruisers; Brummer, armored gunboat, and the second division of torpedo boats.

The attacking squadron consisted of the Baiern, Hansa, and Friedrich-Karl, armored vessels; Stein (flag ship), Sophie, Olga, and Moltke, cruisers; Blitz, despatch vessel; and first division torpedo boats.

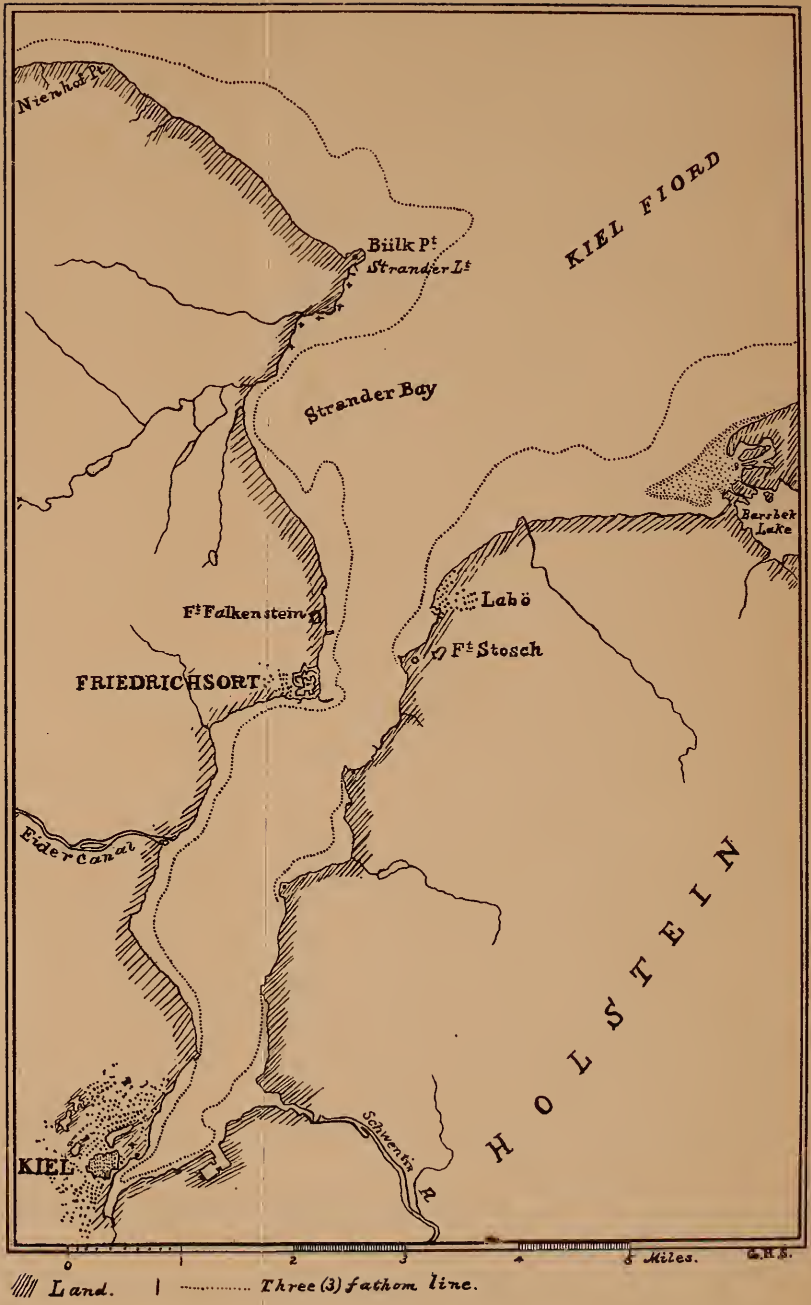
The attacking squadron was sighted at 3 p. m. of the 17th. The Olga advanced for the purpose of reconnoitering, drew the fire of the forts for a short time, and rejoined her squadron.

At 1 a. m. of the 18th the cruisers of the attacking force advanced to reconnoiter the obstructions. Their presence was soon detected, and they were kept in view by means of the electric lights. They withdrew under the attack of the torpedo flotilla of the defense. The night was stormy, with rain.

At 10.30 a. m. of the 18th the attacking squadron came in sight. A brisk engagement then took place between the Hansa and Friedrich-Karl and the forts at Laboe and the Nymphe. In this the Friedrich-Karl was judged to have been destroyed.

The remainder of the defending squadron and torpedo boats then attacked the Hansa and Friedrich-Karl, but the former were driven off upon the arrival of the remainder of attacking squadron in line of battle. The action lasted until 12.30, the Friedrich-Karl and Moltke on one side, and the Nymphe and Fort Falkenstein on the other, were judged *hors de combat.*

At 3.30 p. m. the attacking force renewed the attempt to enter the harbor, and advanced in the following order: First, the armored ships, the Baiern leading, with the Hansa and Friedrich-Karl in rear (group formation). The division of cruisers steered towards the Strander light and manœuvered as if to land their men on the beach. Finding this impracticable, they followed the armored vessels into action.


Nienhof Pt.
Bülk Pt.
Strander Lt.
KIEL FIORD
Strander Bay
Barsbek Lake
Labö
Ft. Stosch
Ft. Falkenstein
FRIEDRICHSORT
Eider Canal
HOLSTEIN
Schwentin R.
KIEL
0
1
2
3
4
5 Miles.
G.H.S.
Land.
Three (3) fathom line.

The manœuvres ended with a landing in force from the combined fleet at Eckenforde, near Kiel and Schleswig. The intelligence and signal department were fully organized and great stress laid upon performance of these duties by day and night. The desirability of great speed for lookouts and scouts was demonstrated.

Nothing is known of the experiments with torpedoes. The density of the smoke was again noticeable as an obstruction to gun practice and as furnishing great opportunities for torpedo-boat attack. Of the various types of torpedo-boats which accompanied the fleet, those of Schichau gave the most satisfactory results both in speed and seaworthiness.

VESSELS TAKING PART IN THE GERMAN MAUŒUVRES.

ARMORED.

Friedrich-Karl.—Broadside battle and cruising ship; launched, 1867; 6,007 tons; sixteen 8.25-inch Krupp B. L.; 13.6 knots; 3,500 I. H. P.; complement, 531.

Baiern.—Barbette battle-ship; launched, 1878; 7,400 tons; one 11¾-inch Krupp B. L.; four 10¼ Krupp B. L.; 14 knots: I. H. P., 5,600; complement, 354.

Hansa.—Central casemate cruising ship; launched, 1872; 3,610 tons; eight 8.25-inch Krupp B. L.; 12 knots; I. H. P., 3,000; complement, 397.

Wespe.—Armored belt and barbette coast-defense gun-vessel; launched, 1876; 1,109 tons; one 12-inch 36-ton Krupp B. L.; 9 knots; I. H. P., 700; complement, 76.

Viper.—Sister ship; launched, 1877.

Mücke.—Sister ship; launched, 1878.

Salamander.—Sister ship; launched, 1880.

Brummer.—Armored barbette and protective deck coast-defense gun-vessel; launched, 1884; 875 tons: one 12-inch 36-ton Krupp B. L.; 14.5 knots; I. H. P., 1,500; complement, 76.

UNARMORED.

Olga.—Spar deck corvette; launched, 1880; 2,169 tons; eight 5.91 inch Krupp B. L.; two 3.42-inch Krupp B. L.; 14 knots; I. H. P., 2,200; complement, 267.

Sophie.—Sister ship; launched 1881.

Moltke.—Gun deck corvette; launched, 1877; 2,857 tons; sixteen 5.91-inch Krupp B. L.; 14.1 knots; I. H.,P 2,500; complement, 404.

Nymphe.—Corvette of old type; launched, 1863; 1,202 tons; nine 5.91-inch Krupp B. L.; 9 knots; I. H. P., 800; complement, 111.

Blitz.—Armed torpedo dispatch vessel; launched, 1882; 1,382 tons; four 5.91-inch Krupp B. L.; two 3.42-inch Krupp B. L.; 18 knots; I. H. P., 2,816; complement, 127.

Pfeil.—Sister ship.

Pommerania.—Paddle dispatch vessel; launched, 1870; 400 tons; one 4.92-inch Krupp B. L.; 13 knots; I. H. P., 700; complement, 66.

Norder.—Sea-going tug; 1882; launched 566 tons; 13 knots; I. H. P., 1,100.

Zephir.—Paddle harbor tug; launched, 1870; I. H. P., 250.

The battle ships and cruisers carry secondary batteries of Hotchkiss R. C. and R. F. G., also Whitehead or Schwartzkopff torpedoes. The gun and dispatch vessels carry R. F. G.

AUSTRIA.

An Austrian squadron of evolutions was commissioned in May, 1885. This consisted of the armored ships Lissa, Kaiser Max, Prinz Eugen, Ferdinand Max, and Habsburg, the torpedo-ship Kaiserin Elizabeth, and six torpedo-boats.

The principle battle manœuvres took place on the night of the 28th of June. The general plan was as follows:

A flotilla of torpedo boats, while cruising in the waters of Zara, receives telegraphic information that a hostile fleet of armored vessels had passed Lissa, from the southward, on the morning of the 28th of June. The flotilla is to seek this fleet and endeavor to approach it unobserved, and by a concentrated attack to destroy it, or to inflict upon it sufficient damage to cause its withdrawal from Austrian waters.

The squadron of armored ships (under a rear-admiral and commodore as divisional commanders) were formed in double column at close order, under the Vice-Admiral Baron Sterneck, commander-in-chief, whose flag was borne by the paddle-wheel steamer Greif.

The squadron passed the light-house on Point Bianche fully prepared to engage torpedo-boats. At night-fall twelve electric lights were put into operation, so as to encircle the squadron with a lighted zone, in which the approach of torpedo-boats might be detected.

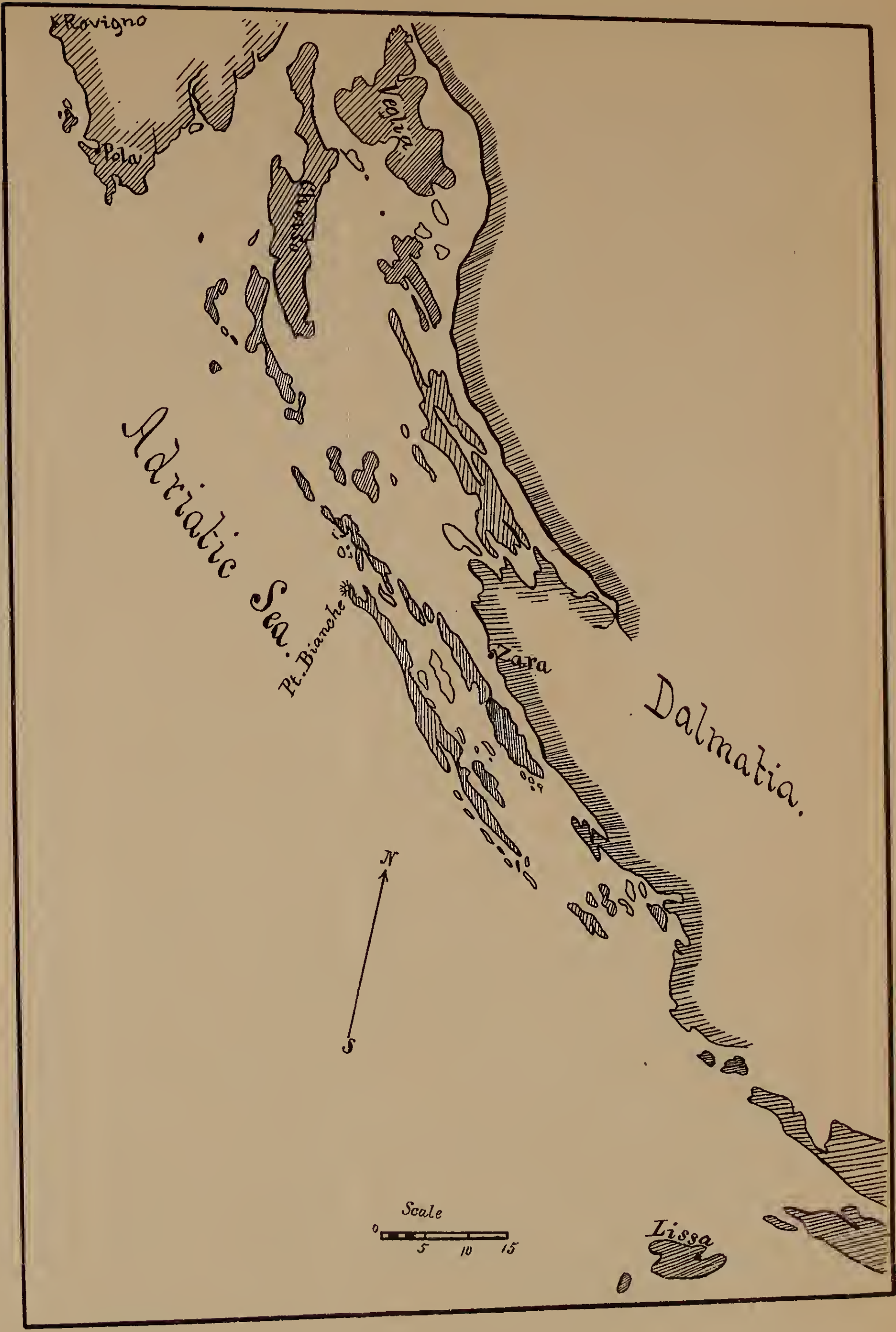
At 10 p. m. a gun from the Lissa gave the alarm that the torpedo-boats had been sighted, and soon after the rattle of machine-gun and small-arm fire indicated that the squadron was engaged with attacks from many directions. It was adjudged that the attacks had been repulsed. A whistle from a single torpedo-boat indicated that it alone had discharged its torpedo within supposed effective range. The judges, however, decided that the torpedo was discharged out of range.

Several of the torpedo-boats carried electric lights, and these were used to enable the boats to rally after the attack. No further attack was attempted, and the boats withdrew. The squadron then proceeded to execute several tactical manœuvres.

The torpedo-boats had discovered the enemy's squadron about 8 p. m., and followed it at a distance of two or three miles without being discovered. The boats then attacked the squadron from different directions, timing their individual operations so that the attacks might be simultaneous. This was effected with great success and accuracy.

The failure of the attack has been ascribed to the bright moonlight, which revealed to the fleet the movements of boats.

The attack of the 28th June was the striking feature of the manœuvres, which continued until the 15th July. All operations and manœuvres were conducted on a war basis. They indicate the high training of the officers and reaffirm the apparent hopelessness of a torpedo-boat attack unless under the cover of complete darkness, smoke, or fogs.


Rovigno
Pola
Cherso
Veglia
Adriatic Sea.
Pt. Bianche
Zara
Dalmatia.
N
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Scale
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5
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15
Lissa

VESSELS TAKING PART IN THE AUSTRIAN MANŒUVRES.

ARMORED.

Lissa.—Central casemate battle and cruising ship; launched, 1869; 6,080 tons; twelve 9.5 inch Krupp B. L.; two 3.5-inch Uchatius B. L.; 13.3 knots; I. H. P., 4,100; complement, 478.

Kaiser Max.—Single-deck, central casemate cruising ship; launched, 1875; 3,550 tons; eight 8.3 inch Krupp B. L.; five 3.5-inch Uchatius B. L.; 12 knots; I. H. P., 2,890; complement, 355.

Prinz Eugen.—Sister ship; launched, 1877.

Habsburg.—Old type broadside battle and cruising ship; launched, 1865; 5,140 tons; fourteen 8.3-inch Krupp B. L.; four 3.5-inch Uchatius B. L.; 12.5 knots: I. H. P., 3,150; complement, 477.

Ferdinand Max.—Sister ship.

UNARMORED.

Kaiserin Elizabeth.—Paddle dispatch and transport vessel; launched, 1854; 1,570 tons; four 3.54 inch Uchatius B. L.; 11 knots; I. H. P., 800; complement, 167.

All of these ships carry secondary batteries of machine and R. F. guns.

NORWAY.

The imminence of war between England and Russia, and the responsibilities attaching to Norway as a neutral power in consequence thereof, caused the yearly naval manœuvres of 1885 to be on a larger scale than usual. The chief object of these was to ascertain how quickly submarine mines could be placed as a barrier to the entrance of Christiana and to practice the naval establishment in such operations and tactics as it would engage in to defend the neutrality of the great ports.

The principal obstructions were to be placed in the channels at Drobak, under the cover of land defenses and a fleet.

The following vessels of different classes took part in the manœuvres: The Nidaros (flag-ship), the Ellida, first-class gunboat; the Vidar, Brage, and Nor, second-class gunboats; the Skudesnaes, Aasgaardstrand, Karmoe, Kristianssand, Skien, and Kongsberg, third-class gunboats; two first-class torpedo-boats (the Lyn and Glint); two smaller torpedo-boats (the Rap and Ulven), one steam launch, fourteen ships' boats, two steam floating derricks, one store-ship, one transport, with explosives and mine stores, one coal vessel, and five lighters.

The gunboat division was put in commission on May 30, and the torpedo division (consisting of all the above-named vessel except the gunboats) June 5, at Horten.

Several days were spent in taking stores, &c., and on the afternoon of the 9th the squadron proceeded to Sandspollen.

The first week after arriving at Sandspollen was spent in landing the stores and material. Station-houses were erected and electric and telegraph cables were laid between the stations. At the same time the crews were drilled as infantry and the officers and petty officers were exercised in firing the revolving cannon of the torpedo-boats.

During the next week, June 15 to 21, the same work was continued, instruments were placed in the station-houses, conductors led to the lines of mines and tested, and examination made to ascertain that all was in working order. The mine-field was laid across the west channel, while the east channel was left open and buoyed for the passage of vessels.

On the 18th June the first-class torpedo-boats made a series of speed trials. The Lyn developed a speed of 18 knots, while the Glint made but 16.75 knots. It was decided to change the propeller of the latter. This was accomplished with the assistance of one of the floating derricks by lifting the stern out of water. With the new screw the boat made about the same speed as the Lyn.

On the 22d the two mine-laying vessels began to place the mines, the gun-boat division acting as guard over them.

The mines were laid in the week ending the 27th; the coast was reconnoitered from Sandspollen to Filtveldt, preliminary to landing men for operations on shore; infantry drills and target practice were continued; and the gunboat division engaged in tactical evolutions.

On the morning of the 29th the landing force from the gunboats disembarked at Filtveldt and proceeded to take possession of the neighboring heights commanding Oscarsborg. The torpedo flotilla acted with the defense. The engagment ended at 4 p. m., the attacking force having been repulsed.

The next day the squadron, consisting of the Ellida, Vidar, Brage, the steamer Alger, Skudesnaes, Aasgaardstrand, and torpedo-boats Glint and Ulven, attacked the defenses of Oscarsborg. The first four represented armored vessels, and the third-class gunboats acted as countermining vessels.

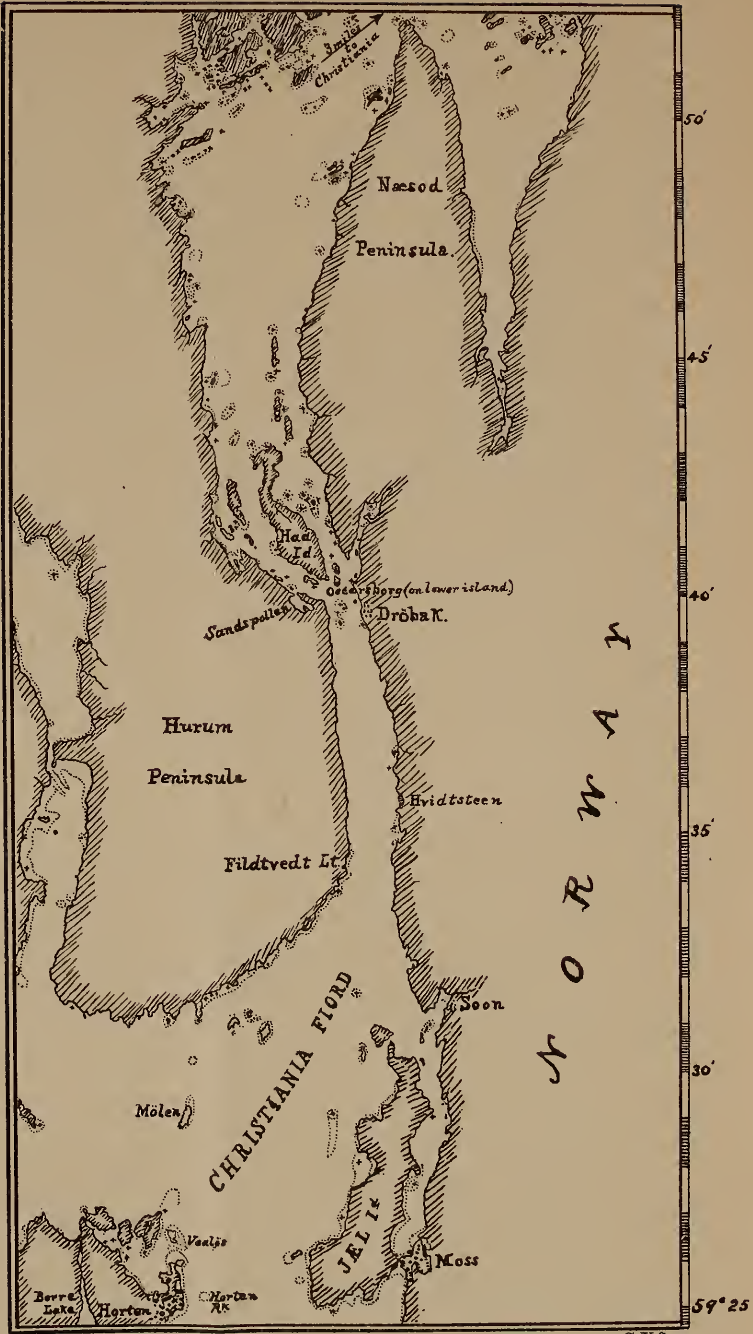
The defending fleet consisted of the Nor, Karmoe, Kristianssand, Skien, and Kongsberg, with the two floating derricks representing monitors, and the smaller torpedo-boats.

An engagement took place, at the end of which the Oscarsborg batteries were declared to have been silenced, the defensive fleet out of action, and the countermining vessels to have been blown up while attempting to open the mine-field, so that the mine obstructions still remained to oppose the passage of the fleet, unless the wires should be cut by a landing force.

This ended the attack. The stores were re-embarked, the mines and cables removed. While this was being accomplished the gunboats engaged in target firing at moving objects, and in an exceedingly practical and instructive exercise of ramming (being protected for this purpose by a double row of fascines to prevent injury from the shock of collision).

The squadron returned to Horten on the 8th July and was put out of commission.

The manœuvres extended over a period of thirty-seven days, at an expense of about 19,000 crowns (about $5,000).


3 miles to Christiania
50'
Næsod
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Had Id
Oscarsborg (on lower island)
Dröbak
Sandspollen
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Hvidtsteen
35'
Fildtvedt Lt.
NORWAY
Soon
30'
CHRISTIANIA FIORD
Mölen
JELÖ
Vealös
Moss
Borre Lake
Horten
Horten Rk.
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G.H.S.

VESSELS TAKING PART IN THE NORWEGIAN MANŒUVRES.

Ellida.—First-class gunboat; launched, 1880; 1,006 tons displacement; armament, five 15 centimetre, one 12 centimetre B. L. R., two 37 centimetre Hotchkiss; speed, 12 knots; 900 H. P.; complement, 130.

Brage, *Nor*, and *Vidar.*—Second-class gunboats; launched, 1881; 255 tons; armament, one 27 centimetre M. L. R., one 37 centimetre Hotchkiss; speed, 8 knots; 210 I. H. P.; complement, 40.

Aasgaardstrand, *Skudesnæs*, *Kristianssand*, *Skien*, *Kongsberg*, and *Karmoe.*—Third-class gunboats (wood); 60 tons; armament, one 17 centimetre converted M. L. R.; 7 knots; 70 I. H. P.; complement, 19.

The Ellida and Nor have Whitehead torpedo outfit.

BRAZIL.

The Brazilian manœuvres took place at Rio de Janeiro, October 16, 1885, under the command of Baron de Jacequay. The scheme of operations was as follows: A squadron, consisting of the Riachuelo, Solimoes, Guanabara, and Almirante Barroso, was supposed to have forced an entrance into the bay, and after silencing the batteries of Fort Villagagnon and Cobras Island, to have anchored off the arsenal, in a position most favorable to destroy it and its neighboring store-houses. The second-class torpedo-boat of the Riachuelo and the steam launches of the ship were to assist the squadron in its operations. Fire was to be opened at 9 a. m.

The defense relied chiefly upon its torpedoes and torpedo flotilla, consisting of four first-class boats and three second-class Thornycroft spar-torpedo boats. Under the cover of the smoke caused by the anticipated bombardment by the squadron, the torpedo-boats were to attack and, if possible, destroy the vessels. It was ordered that each of the four first-class boats should, from different directions, and, taking advantage of the shelter of surrounding islands, simultaneously attack one of the vessels of the attacking squadron.

The following was the programme of operations:

The second-class torpedo-boats to follow the first boats at a distance of 100 to 200 yards. The larger boats to attack at full speed, and may discharge their Whiteheads when within a range of 400 metres.

The spar-torpedo boats to take advantage of the smoke to attack when possible. It was considered that in the excitement and smoke of battle artillery and machine-gun fire would be efficient only when within the range of 800 metres, while the effective range of the Whitehead was placed at 400 metres, thus leaving a dangerous zone of 400 metres for the torpedo-boats to cross. This zone was marked by buoys. In case a torpedo-boat crossed this zone at a speed exceeding 16 knots—that is, in fifty-two seconds or less—it should be conceded that it could have reached, with comparatively little danger, the limit of its effective range, and should be allowed to discharge its Whitehead. In order to ascertain whether the attacking boats' speeds were 16 knots or greater, buoys were placed at 493 metres from the exterior limit of the dangerous zone, which distance should be traversed within *one* minute. An umpire was stationed in each boat. The commander-in-chief was to indicate which boats were placed *hors de combat*, having in view speed and manner of handling. These were to be taken in charge of by the boats of the squadron.

All vessels (except the Riachuelo whose water-tight compartments are of the most approved system) to be considered destroyed whenever a Whitehead is fired at them, and they were to manœuvre to save their crews.

The great and machine gun fire to be deliberate and aimed at some object; not fired at random. The merits of the fire to be adjudged by the commander-in-chief, having in view the number of shots, the caliber and mounting of the guns.

After the torpedo attack the ships to cease firing and proceed to land the naval brigade on the island of Cobras.

The boats to form for landing in order of battle in three columns; the landing to be effected simultaneously at three different points.

The brigade to be marched in review before the Emperor.

According to this programme the squadron took position, having first cut the telegraph cable and operated against a mine-field supposed to have been in the neighborhood of the anchorage.

At 9.07 a. m. the bombardment of the arsenal began. There was a light land breeze blowing, which carried the smoke clear of the squadron and left it distinctly visible to the attacking torpedo-boats as they came out from behind the islands. As these boats were seen the bombardment ceased, and the ships opened upon them with machine-gun and small-arm fire, as well as with that of the great guns.

Torpedo-boat No. 3 advanced with a speed of 19 knots, and at the distance of 400 meters discharged its torpedo at the Riachuelo. No. 2 safely crossed the dangerous zone and fired at the Guanabara. Nos. 4 and 5 did not attain the speed of 16 knots and were destroyed. (?)

The spar-torpedo boats followed, with the intention of using their torpedoes against the vessels supposed to have been injured by the Whiteheads. Their torpedoes were exploded (for practice) at a distance of 50 metres.

During the bombardment and fire against torpedo-boats (about 15 minutes) 926 rounds were fired from the guns of the squadron; or at the rate of one round in every 1.1 seconds, and 10,000 rounds were fired from the machine guns and small arms.

At 9.27 signal was made to "cease firing" and "prepare to land."

The remainder of the programme was then executed.

No accident of any kind occurred.

VESSELS TAKING PART IN THE BRAZILIAN MANOEUVRES.

ARMORED.

Riachuelo.—Two turret cruising and battle ship; launched, 1883; 5,791 tons; four 9.2-inch 20-ton Armstrong B. L., four 5.75-inch Armstrong B. L.; 16 knots; I. H. P., 7,336; complement, 250.

Solimoes.—Two-turret coast-defense ship; launched, 1876; 3,600 tons; four 10½-inch Whitworth M. L. R.; 12 knots; complement, 111.

UNARMORED.

Guanabara.—Spar-deck corvette; launched, 1877; 1,911 tons; nine 6-inch Whitworth M. L. R.; 12.5 knots; complement, 257.

Almirante Barroso.—Spar-deck corvette; launched, 1882; 2,200 tons; eight 4.72-inch Whitworth M. L. R.; 12.5 knots; I. H. P., 2,200; complement, 317.

All of these ships carry secondary batteries of Nordenfeldt machine guns and R. F. guns.

NOTES

ON

THE DESIGN OF WAR-SHIPS,

WITH A

COMPARISON OF SOME RECENT TYPES,

BY

W. I. CHAMBERS,
Lieutenant (junior grade), U. S. Navy.

Part I.—BATTLE-SHIPS.
Part II.—CRUISERS.
Part III.—OTHER VESSELS OF FLEET SERVICE TYPES.
Part IV.—NAVAL TACTICS.
Part V.—COMPARISON.
Part VI.—DESIGN.

NOTES ON THE DESIGN OF WAR-SHIPS, WITH A COMPARISON OF SOME RECENT TYPES.

By W. I. Chambers, Lieutenant (junior grade), U. S. Navy.

Part I.—Battle-Ships.

The representative battle-ships of to day differ greatly in design. They differ principally in the allotment of weights to the antagonistic elements of offense, defense, speed, and endurance.

The most striking point of difference, however, is the allotment of weight, or the distribution of armor, in that important part of the element of defense known as the "protection to stability."

The French, following the designs of the celebrated M. de Bussy, have adhered, until quite recently, to a complete armor belt at the water-line, and this policy is still advocated in England by the distinguished ex-Chief Constructor E. J. Reed, and many eminent English naval officers.

In Italy a total abandonment of side armor has taken place in the largest and most remarkable battle-ships of the age, designed by the talented Signor Brin, and this idea is also advocated in England by Sir W. G. Armstrong, and many distinguished naval officers.

In England the building policy of the English navy, for a period of over ten years, has been shaped by those who advocated the "central citadel system," a medium between the two before mentioned, and stoutly defended by Mr. Nathaniel Barnaby and Mr. W. H. White.

Recent contributions to the literature on the subject form most important links which it will be my first aim to connect with the chain of reasoning which the general reader finds in such compilations as King, Very, Brassey, and Tromp.

It will be remembered that the English, recognizing the advantages of our coast defense monitor type, endeavored to adapt that type to sea-going battle-ships when the Devastation, Thunderer, and Fury were laid down. In 1870 these ships were pronounced unsafe by eminent naval officers, and a careful investigation of the subject was made by a "special committee on designs" appointed for that purpose. One part of their exhaustive report reads as follows:

> Before quitting this part of our subject we desire to remark that although, as before pointed out, there are serious difficulties in the way of increasing to any very material

> extent the thickness of armor applied in the usual manner to sea-going ships, viz, in the form of a complete belt around the ship, from stem to stern, at the water-line, besides local protection for guns, men, &c., it is not by any means certain that some method may not be devised of securing the requisite reserve of buoyancy by other means than armor plating. Were this accomplished, the area of the armor might be diminished and its thickness increased in a corresponding degree. The ship would then comprise a very strongly-plated central citadel, surrounded and supported by an unarmored raft, constructed on a cellular system, or containing some buoyant substance, such as cork, which, without offering any material resistance to the passage of projectiles, would not be deprived of its buoyancy by penetration.

Certain modifications, increasing the stability of the ship somewhat, were recommended, in accordance with which the Devastation and Thunderer were finished. Abut this time Mr. Reed left the Admiralty, and his design of the Fury was somewhat modified, though still retaining the essential features upon which he laid great stress, the complete water-line belt and central armored battery, and her name was changed to Dreadnought.

Many of the critics who then denounced the type now claim that the Dreadnaught embodies the principal features of an ideal battle-ship.

In 1872–'73 the Italian naval authorities, accepting the views of the British "committee on designs," trusting for both buoyancy and stability to an unarmored raft, laid down the first "central-citadel" battle-ships, the Duilio and Dandolo, of over 11,000 tons each; and about this time Mr. Barnaby, then chief constructor of the English navy, brought forward a similar design for the Inflexible, of 11,400 tons, which ship was commenced in 1874 and launched in 1876.

The salient features of this design are (1) an armored box-shaped citadel, protecting engines, boilers, and the bases of two turrets situated *en echelon* above it; (2) a horizontal armored deck extending from the base of the citadel, at a distance of 6½ feet below the load water-line, to the stem and stern-post, and protecting magazines and other submerged spaces from plunging fire; (3) an unarmored superstructure above this deck, completing the freeboard, and having the unarmored spaces at the water-line subdivided into water-tight compartments, filled with coal and other stores, the greater part of which, in two groups, are surrounded by cork-filled and coffer-dam compartments.

The construction of this vessel advanced rapidly, the British public happy in the belief that its Government would soon possess the most perfect war ship ever floated, when suddenly, consternation was created by the announcement that several prominent naval architects outside the Admiralty doubted her safety.

Mr. Reed stated in Parliament and in the public prints that the cork and stores might be shot away in action, the armored ends might be riddled and water-logged, and that in such an event, though the citadel remained intact, the ship would capsize.

The Admiralty replied that the supposed case was too remote a possibility to be seriously considered, and that even without any unprotected ends the ship would still float and have a safe margin of stability. The celebrated "Inflexible committee" was then appointed to investigate the matter, and after a very exhaustive and elaborate series of calculations sustained the views of the Admiralty.

Accordingly, in 1879, the Inflexible design was repeated in the English sister ships, Ajax and Agamemnon, of 8,510 tons each, and afterwards in the Colossus and Edinburgh, of 9,150 tons each. The Italians, too, evidently satisfied with the Duilio and Dandolo, perpetuated the central-citadel design in laying down the Ruggiero Lauria, Andrea Dorea, and Francisco Morosini, which are of 10,500 tons each, and of the same type.

The central-citadel type has been further repeated in the recent English "Admiral class," of which the Camperdown is an example, and in which the citadel has been reduced in size, its armor-covered roof being but 2½ feet above the load water-line, and its length 150 feet, the length of ship between perpendiculars being 330 feet.

THE CAMPERDOWN.

(Plate I.)

This ship was laid down in 1882 and launched in 1885.

Principal dimensions.—Length between perpendiculars, 330 feet; extreme breadth, 68 feet 6 inches; draught, forward, 26 feet 3 inches; aft, 27 feet, 3 inches; displacement, 10,000 tons

The hull is of steel; the double bottom occupies about 256 feet of the length; the hold is divided by nine complete transverse and several partial longitudinal bulkheads into numerous water-tight compartments.

The vertical side armor (compound) extends 150 feet along the side in a strip 7½ feet wide, reaching to 2½ feet above the load water-line, and is from 18 to 13 inches thick; the armored bulkheads of the citadel are 16 inches thick; the armored deck above it is 3 inches thick, and the protective deck at the ends varies from 2½ to 3 inches in thickness.

The armor on the barbettes is from 12 to 14 inches, on the ammunition hoists 12 inches, and on the conning tower 12 inches. The armor backing of teak varies from 10 to 15 inches in thickness.

The armament consists of four 13½-inch 63-ton B. L. R. *en barbette* and six 6-inch 4-ton B. L. R. mounted under cover in broadside, the four end guns of the broadside battery having shifting pivots to allow of their being fired through ports in the forward and after bulkheads of the superstructure, which is protected by 6 inches of compound armor. The secondary battery includes twelve 6-pounder R. F., ten 1-inch Nordenfelds, and four light Gardner machine-guns. The torpedo battery consists of five Whitehead launching tubes, four in broadside and one ahead, all above water.

The motive power consists of two sets of three-cylinder vertical inverted compound engines, in two separate compartments, actuating twin screws. I. H. P. under forced draught estimated at 10,000 for a speed of 16 knots, and under natural draught 7,500. There are twelve three-furnace oval boilers, in four separate compartments, and there are also thirty-six auxiliary engines.

The total coal capacity is 1,150 tons, or 900 tons at the normal draught; endurance 1,764 miles at full speed, or 5,176 miles at 10 knots; complement, 445 officers and men.

The weight of armor carried is 2,942 tons, and the weight of barbettes, including guns and mountings, is 1,420 tons.

The sister ships of this class differ in respect of the armament carried *en barbette*, and are as follows: Collingwood, 9,150 tons, launched in 1882, four twelve-inch 43-ton B. L. R.; Rodney, 10,000 tons, launched in 1884, four 13½-inch 63-ton B. L. R.; Howe and Anson, 10,000 tons each, launched in 1885, four 13½-inch 63-ton B. L. R. each; and the Benbow, 10,050 tons, launched in 1885, two 17-inch 110-ton B. L. R.

The two similar battle-ships, the Renown and Sanspareil, laid down in 1885, also embody the structural features of the admiral class as regards protection to stability.

THE RENOWN.

(Plate I.)

Principal dimensions.—Length between perpendiculars, 340 feet; extreme breadth, 70 feet; draught forward, 24 feet 6 inches; aft, 27 feet 3 inches; displacement, 10,500 tons.

The hull is of steel, with double bottom under engines, boilers, and magazines, and the hold is divided by transverse and longitudinal bulkheads into numerous water-tight compartments. As in the Admiral class, the space above the protective deck at the ends and the armored deck above the citadel is divided into many compartments, filled with coal, water, and other stores.

The side armor is compound, 16 inches thick at water-line, backed by 6 inches of teak, behind which is an unusually thick skin of 2 inches of steel further supported by a cellular structure. The bulkheads of the citadel are 16 inches, the pear-shaped redoubt which protects the base of the turret is 16 inches, and the conning tower 16 inches, and the turret armor itself is 18 inches in thickness.

A novel feature in the design is the situation of the magazines and shell rooms amidships between the boiler and engine compartments about 10 feet above the keel.

The armament consists of two 17-inch 110-ton B. L. R., in a closed revolving turret, having a train from ahead to 60° abaft the beam; twelve 6 inch 4-ton B. L. R., in broadside, protected by 3 inches of armor at the sides, by heavy traverses between the guns, and by a partial bulkhead of 6 inches of armor at the forward end of the superstructure in which they are mounted; and one 9-inch 18-ton B. L. R., mounted as a stern central pivot, having a train to 30° forward of the beam. The after broadside guns can fire astern. The secondary battery includes twelve 6-pounder R. F. and other machine-guns, and the torpedo battery five launching tubes, four in broadside and one ahead, all above water. The motive power will be vertical inverted triple expansion engines, situated in two separate compartments, and driving twin screws. I. H. P. estimated at 10,000 to 12,000; speed, 16½ knots; weight of machinery, 1,080 tons.

In the mean time the French were building their battle-ships of 8,000 tons and upwards, after the designs of M. de Bussy, to carry complete water-line belts, and a central armored casemate to protect the heavy guns.

In 1878, however, the armored casemate, hitherto a prominent feature in French design, was abandoned when the Admiral Duperré was laid down, and the height of the belt above the load water-line was reduced.

THE ADMIRAL BAUDIN.

(Plate I.)

The Admiral Baudin, designed by M. Godron, was laid down in 1879, and launched in 1883.

Principal dimensions.—Length, between perpendiculars, 321 feet 6 inches; length over all, 342 feet; extreme breadth, 69 feet 10 inches; mean draught, 25 feet 9 inches; displacement, 11,441 tons.

The hull is built of steel and iron; the double bottom extends throughout the length occupied by engines, boilers, and magazines; the hold is subdivided by eleven transverse and one longitudinal water-tight bulkheads, which reach to the armored deck, which is 3 feet 7 inches above load water-line, extending from stem to stern at the top edge of the armor-belt, and is 3.15 inches thick near the extremities; 3.93 inches thick over engines and boilers.

The armor-belt is of steel, and complete, is 21.6 inches thick at middle, 13.9 inches at stern, and 14.2 inches at the bow, backed by 11 to 14 inches of teak.

The barbette towers are 15.7 inches thick; the ammunition hoists 7.2 inches in diameter and 15.7 inches thick.

The armament consists of three 16½-inch 75-ton B. L. R. in the barbettes, protected by machine-gun-proof shields, and twelve 5½-inch B. L. R. in broadside on covered gun-deck, so arranged as to be transportable all to the same side. The secondary battery consists of eight Hotchkiss R. F. guns, and numerous 37-millimeter revolving cannon, several of which are in the military top of the one steel mast. Several tubes for discharging Whitehead torpedoes are situated in compartments above the armored deck.

The engines are three-cylinder vertical inverted compound, actuating twin screws, and situated in two separate compartments. I. H. P.

estimated at 8,320 with forced draught, and estimated speed more than 15 knots. There are twelve three-furnace boilers.

The coal capacity is 800 tons; endurance 1,650 miles at maximum speed, 3,000 miles at 10 knots, and the complement 500 officers and men.

Weight of armor-belt, 1,980 tons; of armored deck, 1,058 tons; and of barbette towers, including ammunition hoists, 911 tons.

The Formidable, a sister ship, was launched in 1885, and will have triple expansion engines.

THE MARCEAU.

(Plate I.)

The Marceau was designed by M. Huin, and launched in 1884.

Principal dimensions.—Length between perpendiculars, 323 feet 6 inches; length at load water-line, 330 feet; extreme length, 339 feet 9 inches; extreme breadth, 65 feet 11 inches; depth of hold, 25 feet 7 inches; draught forward, 26 feet 2 inches; aft, 28 feet 2 inches; displacement, 10,581 tons.

The hull is constructed of steel and iron, the outer skin being of iron to the armor-shelf; the double bottom extends throughout the length occupied by engines, boilers, and magazines; the hold is divided by thirteen transverse bulkheads into fourteen water-tight compartments, and the longitudinal bulkheads at the sides give seventeen additional compartments. The flooding of any compartment will not admit more than 250 tons of water. The space above the armored deck is also divided into numerous compartments, and the superstructure is entirely of steel.

The armor-belt extends about 12 inches above load water-line, and is from 13.7 inches to 17.7 inches thick; the armored deck is 2.6 inches thick, and the barbette towers 15.7 inches thick.

The armament consists of four $13\frac{4}{10}$-inch B. L. R. in the barbette towers, one $5\frac{1}{2}$-inch B. L. R. at the bow, and sixteen $5\frac{1}{2}$-inch B. L. R. in broadside. The secondary battery will include twenty Hotchkiss guns, and four torpedo launching-tubes above water (two in broadside and two astern) will be provided. The magazines and shell-rooms are situated directly beneath the gun-towers.

The motive power consists of two independent sets of vertical inverted compound engines in separate compartments, actuating twin screws. I. H. P. at natural draught, ~~8~~,548; at forced draught 12,000, with 90 revolutions. Estimated speed 16 knots. There are 8 three-furnace boilers, in pairs, in four separate compartments.

The total coal capacity is 800 tons, or 600 tons at normal draught; endurance 1,500 miles at full speed, or 3,500 miles at 11 knots.

The weights are distributed as follows: hull, 3,740 tons (about .35 of displacement); machinery and boilers, 1,300 tons; artillery, 850 tons; armor, 3,190 tons; coal, 600 tons; other weights, 900 tons.

The sister ships laid down about the same time are the Hoche, Magenta, and Neptune.

During the building of the Admiral class in England adverse criticism continued to grow apace, a great many naval officers taking sides with Sir E. J. Reed.

A very able paper was read at the Royal United Service Institution by Captain Fitzgerald, R. N., in which he argued that in order to form any correct estimate of the value of armor, the main point to be considered is the nature of the projectiles which it will probably be called upon to resist, and denied the oft-quoted words of Sir W. G. Armstrong, that "every improvement in guns and projectiles tends to lower the value of armor." He held that the improvement in machine-guns and the rapid-firing six-pounder had a contrary tendency; that the increase in size of guns and weight of projectile would probably act in that direction, but that the number of heavy guns must be few and their fire slow in comparison with the smaller guns.

In defense of side armor he urged—

> First. If it does not keep out solid shot it will keep out large-capacity shell, which would do infinitely more damage; secondly, the great majority of projectiles which strike a ship in action would not be at right angles or at point-blank range; thirdly, the fire from the light and machine guns would have a terribly destructive effect on the ship unprotected by armor, as every shell would burst inside the ship with deadly effect.

He also submitted several suggestions, one of which was to the effect that, from a naval point of view, it was a fatal error to leave two-thirds of the water-lines of England's battle-ships unplated, and therefore penetrable by a hail of machine-gun fire, seeing that it would render their seaworthiness at least doubtful. And he then declared that the so-called citadel ships should be altered immediately, the whole of the armored deck being taken away except patches to cover the crowns of the magazines, and if necessary other weights should be taken away—coal or even guns and ammunition—so as to enable them to be given a complete water-line belt of armor, at least thick enough to keep out light and machine gun fire.

In an editorial criticism (see Engineering, March 6, 1885) occurs the following:

> We will assume, though we cannot admit, that the number of projectiles striking at the water-line would be as great as the lecturer thinks, and suppose his suggestion as to the 3-inch belt carried out. Now, the Hotchkiss 47-millimeter revolving cannon of the latest type, and which is much in vogue with foreigners, can penetrate 3 inches of steel at 500 yards, and this is only a machine-gun; while the 6-pounder rapid-firing gun will pierce 3½ inches easily at the same distance; therefore, supposing everything to stand as at present, the proposed 3 inches of steel would perhaps be just efficient to keep out the greater part of the light shot.
>
> But can we for one instant expect to remain *in statuo quo;* indeed, have we not already made an advance by the introduction of supplementary 6-inch guns (in the Colossus), capable of firing two to three rounds a minute, and penetrating (with steel shell) 8 inches of steel at 1,000 yards; and 25-pounders, firing five to six rounds per

minute, capable of penetrating 4 inches of steel at 1,000 yards? Do we not hear of one of the great machine-gun manufacturers constructing a 32-pounder rapid-firing gun for a foreign government, and are they not all prepared to increase the size and power of the rapid-firing guns, if required?

In the face of all this, can we for one moment agree with a hard-drawn line fixing the thickness of the belt at 3 inches.

It would only be the same old story over again. As the power of the gun increases, the armor becomes worse than useless, and so we arrive again at the point from which we started.

A very slight thickness of horizontal plating, on the contrary, would be sufficient protection against the heaviest guns, and in conjunction with it the devices for dealing with the water which may get in (which Captain Fitzgerald now stigmatizes as unpractical) should be made practical, for there seems little doubt that it is on them that we shall have to depend.

In the discussion on Captain Fitzgerald's paper Captain Colomb, R. N., was inclined to think the belt question was one of disablement rather than one of destruction; the greater fear without the belt of a loss of trim, or a heavy list, throwing the powers of offense out for a time.

He furthermore scored a good point when he remarked:

I think there is another danger that we face in leaving the ends unarmored, and that is, we accept the unsteady gun-platform. Mr. Barnaby puts it that the inertia is sufficient to get over the difficulty of the high metacenter, but my experience of two of the most recent ships is that they will be very lively. I felt in each of these ships on a light swell as if I were on board a Symonite, and coming from the Thunderer, that steady old rock that nothing disturbs, it occurred to me that the fire from the guns would be very uncertain.

The remarks of Mr. Barnaby to which he refers occur in his annual address, from which I quote:

In order to justify the stoppage of belt armor short of the ends, we consider it desirable to provide an unusually large metacentric height in the intact ship, to provide against loss of it by perforation and water-logging. That there is serious disadvantage in this respect of rolling is shown by the behavior of the Inflexible, where the effect of great metacentric height in quickening and accumulating angles of oscillation is compensated for by the large inertia of the wide and heavy citadel, and is reduced by other means.

When the French naval officers recognize this new condition of things, and no longer fear the heavy rolling they have been accustomed to find invariably associated with a high metacenter, they will probably prefer to accept the better protection of their guns or a reduced size of ship.

The latest designs of M. de Bussy provided for a central citadel with the usual proportions and metacentric height of ship, and with thin armor at the ends of the belt proof to the quick-firing guns. It is conceivable that some such provision against machine-guns might be a wise addition where weights can be surrendered to meet it. In the Agamemnon, for example, 2-inch armor could be put in a belt 6 feet wide with the weight of less than one-third of the ammunition for her turret guns, of which she carries one hundred and eighty rounds, while the Amiral Baudin, of over 11,000 tons displacement, carries only sixty-six, and the Duperré and Dévastation seventy-six.

That it cannot be right to continue armor of anything like the maximum thickness to the ends of the belt, if the question of high metacenter can be put aside, will be clear from the following considerations: (1) There are existing guns capable of perforating the best armor which can be made, 19 inches thick, supported by a far stronger backing than is ever given in a ship; * * * (3) the way in which the complete belt draws upon the other armor may be seen by the following comparison:

Alternative designs with same displacement.	Single turret as approved.	Same ship with belt extended and thinned.	Increase in ship if armor is not thinned in middle and made 12 inches at ends.	Alternative for this increased size with 14-inch armor not carried to ends.
Length ....feet..	335	335	355	355
Breadth .... do....	70	70	70	70
Speed ....knots..	15½	15½	15½	15½
Displacement................	10, 000	10, 000	11, 000	11, 000
Belt	Shortened.	Complete.	Complete.	Shortened.
Thickness on belt ...inches..	18	14 to 12	18 to 12	14
Other armor...........do ...	18	14	18	14
Armament....................	1 turret, 2 110-ton guns.	Same.	Same.	2 turrets, 2 43-ton, 2 110-ton guns.
Battery for small guns.......	Aft covered by 3-inch armor.	Same.	Same.	Amidships with armored traverses only.

(4) The Agamemnon, where the armor is mainly iron from 18 to 14 inches thick, and where the armament is nearly confined to two turrets, any reduction of its thickness would have to be faced, in view of the fact that the shot which wrecked the Spezzia targets is estimated to be capable of perforating 40 inches of unbacked armor.

The very heavily-armed battle-ship has, I consider, only a subordinate part to play, that of preventing in enemies' ships an extension of those armor-proof to light guns. What we want is well-armed and fast ships, having their buoyancy assured by a belt or an equivalent deck.

In the very clever lectures delivered at the Royal Naval College, February 4 and 11, 1885, by Mr. W. E. Smith, M. I. N. A., he claimed as the strong points of the central-citadel system, as exemplified in the Camperdown, the following:

(1) The guns and gunners are exceedingly well protected for the size of ship.

(2) The ventilating tubes communicating with the boilers and engine rooms, and the tubes for bringing the ammunition through, are also equally well protected.

(3) The engines and boilers are better protected against projectiles than if the same weight were carried along in the shape of a complete belt.

(4) The magazines and shell-rooms in the ends of the vessel and the steering gear are much better protected by the under-water deck than if the sides were armored with armor not projectile proof, and the under-water deck removed from where it is underneath the coal and water to the top of a belt above water. The vitals of the ship—her machinery, her powder, or her rudder and steering gear—can only be reached, and the ship disabled by a single blow, provided that blow is much heavier than would suffice if the same weight of armor were more diffused in the shape of a complete belt.

(5) For a length of about one-half of that of the entire length of the ship, viz. the unarmored ends, it is a matter of *non-vital* importance whether a big gun projectile strikes at the water line or not. In a belted ship such a projectile striking at this point might either blow up the ship or completely flood one end and render the magazine useless. The amount of water admitted would, in the belted ship under the above circumstances, be so great as to render her quite unmanageable and an easy prey to her enemy, even if it did not at once sink her outright. In the central-citadel ship the amount of water admitted under these circumstances would be moderate in amount as to leave the ship with her sea-going qualities and fighting qualities practically unimpaired.

He then compared the various points of difference, item by item, between the Camperdown and a hypothetical Camperdown constructed with a complete belt, or an extension fore and aft of the citadel armor, and illustrating his main conclusions by model experiments, he sought to establish the following:

(1) That all modern battle-ships depend for their stability to a large extent on their unarmored parts. Their probability of survival in action, so far as stability goes, depends almost entirely on the improbability of the whole or the greater portion of the unarmored superstructure being completely opened to the sea. The possession of a complete belt along the water line cannot keep a vessel from capsizing if the unarmored superstructure is entirely opened to the sea. A belted ship is no safer in this respect, and is less safe in other respects.

(2) In the under-water-deck system some portion of the superstructure above armor is under water, and is not so easily destroyed as the above-water portions in the belted system.

(3) Although in the under-water-deck system it is practically certain that *moderate* quantities of water will be admitted to the ends of the vessel, it is quite certain that the admission of only moderate quantities will not prejudice the stability of the vessel to an important extent, and will so steady the vessel as to enable her to make good practice with her big guns. On the other hand, it is much more likely that *very large* or *fatal* quantities of water will be admitted to the ends of the belted vessel, and it is also much more likely that the powder and steering gear will be reached in the belted ship by the big gun than in the central-citadel ship, because the thin vertical armor on the belt at the ends and the above-water deck over its top are more penetrable to the big gun than the under-water deck of the central-citadel ship, well covered as it is by the sea and stores on its top.

(4) As regards the loss of speed occasioned by the admission of water, what might be called the smooth-water sinkage of the central-citadel ship causes a loss of only one-fourth of a knot in speed, out of an additional knot it was possible to arrange for in the design to start with.

(5) As regards the loss of speed due to any supposed rushing in of the water through scoop-shaped holes, it is not a difficult thing to let the water out again by holes suitably shaped and properly positioned; and even if it were, this is a defect which is as great in the belted ship as in the under-water-deck ship, because all the time the vessel is steaming at a fighting speed each end of the belt is permanently under water on account of the waves raised by her progress, and the midship part of the belt is half its time under water on account of the rolling of the ship and the passage of sea waves along her side.

(6) That the central-citadel system with under-water decks at the ends protects the magazines in the ends of the ship, the steering gear, and supports the ram much better than the belted system does, and at the same time provides, on a given weight of armor, a very much thicker belt amidships than the belted system does, and as a consequence gives greater protection to the engines and boilers also

(7) That with the central citadel and under-water decks the admission of water to one end alters the trim so little as to leave it a matter of option and not of necessity with the commanding officer whether he will voluntarily admit water to the other end or not. If water be voluntarily admitted to the ends before going into action there can be no further derangement of trim, the vessel will be quite safe, will be almost perfectly steady, and will have lost only one-fourth of a knot in speed out of an additional knot provided for in the original design.

In these lectures the Camperdown was capitally defended, but in the fictitious Camperdown too much was left to the imagination for a fair comparison.

All the questions concerning a redisposition of weights when a change of design is contemplated are so intimately connected that it is to be regretted that Mr. Smith did not select some actual exponent of the complete-belt system, the Amiral Duperré, for example, for his comparison, assuming each to be the best combination of the prominent features in the system it represents.

Considerable controversy has appeared in the English press of late which throws much light upon this subject, and several of the letters, of unusual interest, deserve to be quoted extensively.

The following letter appeared in the Times (London) of April 4, 1885:

SIR: May I request the favor of space in the Times in which to comment upon the opinions recently expressed by Sir Edward Reed and other writers respecting the designs of the Admiral class of ships in the royal navy, and the four central-citadel ships which were laid down subsequently to the Inflexible?

Having been closely associated with Mr. Barnaby in the designing of all these ships, with the exception of the Ajax and Agamemnon, I can speak with full knowledge of both the history and intentions of the designs.

Moreover, my share of the responsibility for the professional work involved in those designs remains, although my official connection with the constructive department of the Admiralty was severed years ago. It need hardly be added that the remarks which follow simply embody my own opinions, and that I write neither as an apologist for Mr. Barnaby nor as a champion of the ship-building policy of the Admiralty.

The sweeping condemnation which has been pronounced against the most recent English battle-ships is based upon the consideration of one feature only in their fighting efficiency, viz., the extent of the armour protection of their sides in the region of the water-line. There has been no discussion in the letters to which I have referred of the comparative speeds, armaments, or other qualities of the French and English ships. But the fact that the French ships are armour-belted from end to end, while the English ships have no vertical armour on considerable portions of the length at the region of the water-line, is considered by Sir Edward Reed so serious a matter that he says: "The French armoured ships must in all reason be expected to dispose of these English ships in a very few minutes by simply destroying their unarmoured parts."

From this opinion I most strongly dissent, for reasons which are stated below; and I venture to assert that if attention is directed simply to the possible effects of gun fire, while the possibly greater risks incidental to attacks with the ram and torpedo are altogether neglected, then there is ample justification for the belief that the English ships of recent design can do battle on at least equal terms with their contemporaries in the French or any other navy.

In all recent armoured ships if the wholesale and extremely rapid destruction of the unarmoured portions of the ships which Sir Edward Reed contemplates actually took place, very considerable risks would undoubtedly result; but in my judgment these risks are not sensibly affected by the different distribution of the armour on the ships of the two great navies. And, further, there is every reason for doubting whether such wholesale destruction of the unarmoured parts could be effected with the appliances which are now available, not merely in "a few minutes," but in a very considerable time, and under the most favorable conditions for the attack. Nor must it be forgotten that armour, even of the greatest thickness, applied to the sides or decks of ships is not impenetrable to the attack of guns already afloat, while the *mitraille*, which is driven back into a ship when armor is penetrated, is probably as destructive as any kind of projectile can be, and attacks directly the vital parts which the armour is intended to protect.

In support of these assertions I must ask permission to introduce certain detailed statements which appear to be absolutely necessary to a discussion of the subject, but which shall be made as brief and untechnical as possible.

It appears that the points raised by the discussion may be grouped under two heads. First does the shortening of the belt in the English ships introduce such serious dangers if they have to do battle with the French ships? Secondly, what should be considered, the principal uses of armour-plating in modern war ships? The second question may be considered to include the first; but it will be convenient to take the questions in the order in which they have been placed, as, after all, the greatest immediate interest centers in the comparison between existing ships.

At the outset it is important to remark that in the most recent designs of armoured ships for all navies, increase in speed, armament, and thickness of armor has been associated with a decrease in the area of the broadside protected by armour. Further, it has been considered important in most cases to distribute the armoured positions of the heavy guns in the ships in order to reduce the risks of complete disablement of the principal armament by one or two lucky shots which may happen when the heavy guns are concentrated in a single citadel or battery. This distribution of the heavy guns also gives greater efficiency to the auxiliary armament of lighter guns, and enables these heavy guns to be placed at a considerably greater height above water than was usual in former days, so that the chances of the guns being prevented from being fought in heavy weather are diminished, and their power as compared with the lower guns in earlier ships is increased, especially when firing with depression.

The days of the "completely protected iron-clad," with the broadside armoured throughout the length from the upper deck down to 5 or 6 feet below the water line, have long gone by. The "central battery and belt" system has also been practically dropped, whether the battery contained broadside guns or formed a citadel protecting the bases of the turrets. In short, on modern battle-ships there now remains only a narrow belt of armour, rising from 5 or 6 feet below the load-line to 2 or 3 feet above it. This narrow strip of armour in the French ships extends from end to end, and is associated with a protective deck worked at the height of the top of the belt, and forming a strong roof to the hold spaces beneath. In the English ships of the Admiral class the belt of armour extends somewhat less than half the total length, protecting 140 to 150 feet of the central portion of the ship (in which are situate the engines and boilers), and protecting also the communications from the barbette towers to the magazines. At the extremities of the belt strong armoured bulkheads are built across the ships. The protected deck is fitted at the upper edge of the belt over the central portion. Before and abaft the bulkheads where there is no side armour, the protection consists of a strong steel deck, situated from 4 to 5 feet below water, and extending to the bow and stern, respectively. Upon this under-water deck are placed coal-bunkers, chain-lockers, fresh-water tanks, store-rooms, &c., the spaces between it and the deck next above being subdivided into a large number of water-tight compartments or cells by means of longitudinal and transverse bulkheads. A water-tight top or roof to these compartments is formed by plating over the main deck-beams with thin steel at the same height above water as the top of the armour belt. In this manner the unarmored ends above the protective deck are not merely packed to a large extent with water-excluding substances when the vessel is fully laden, but they are minutely subdivided into separate compartments, which can only be thrown into communication with one another by means of very extensive injuries to the partitions.

In all the modern French ships, as well as in the Admiral class, a light steel superstructure of considerable height is built above the level of the belt deck; the living quarters of the crew and the stations of the auxiliary armament are contained within this light erection, which also surrounds the armoured communications from the barbette towers to the magazines. In this manner a ship with a small height of armored freeboard is converted into a high-sided ship for all purposes of ordinary navigation, seaworthiness, and habitability; while spaces are provided in which a more or less considerable number of light guns can be fought concurrently with the heavy guns placed in the armour-protected stations. The radical difference, therefore, between the French ships and the Admiral class, independently of other considerations than the armour protection of the water-line, consists in the omission of the side armour at the extremities, and the use instead of the side armour of the strong underwater deck with cellular subdivision and other arrangements for adding to the protection and securing the buoyancy of the spaces at the ends, into which water may find access through the thin sides if they are shot through and seriously damaged in action. If the completely belted French ship has to fight a vessel of the Admiral class, the latter has obviously the greater chance of damage to the narrow strips of the sides lying above the under-water deck before and abaft the ends of the belt. If the action takes place in smooth water, when the ships are neither rolling nor pitching, but are simply in motion, the chances of hitting these narrow strips in the water-line region might not be very great; but it must be admitted that even the lightest guns would penetrate the thin sides of the English ships and admit more or less considerable quantities of water into the ends. If, on the other hand, the fight takes place in a sea-way, with the ships rolling and pitching, then the relative importance of penetration of these narrow strips of the ends of the English ships becomes much less, because the belt armour of the French ships will be brought out of water for a considerable length of the bow and the stern by a very moderate angle of pitching or by the passage of a comparatively low wave, and because rolling motion of the ships will alternately immerse or emerge the belt armour, even at the midships part, where it has its greatest thickness. In fact, as I have more than once said publicly, it is clearly an error to limit criticism to the longitudinal extent of the belt armour in modern ships and to exclude consideration of the vertical extent of the armour above and below the load-line. Apart from any discussion of the question from the artillerist's point of view or any attempt to determine the probability or otherwise of the wholesale destruction of the unarmoured portions of modern battle-ships by shell-fire from large guns, or by the projectiles from rapid-firing and machine guns, it is perfectly obvious to any one who will examine into the matter that the risk of damage to the light superstructures situated above the belt must be greater than the corresponding risk of damage to the narrow strips of side area exposed at the unarmoured ends of the Admiral class, between the level of the belt-deck and the water-line.

Sir Spencer Robinson, after his inspection of the models shown him at the Admiralty, recognizes the fact that in the French belted ships (of which the Admiral Duperré is an example), if the light sides above the belt-deck are destroyed or very seriously riddled in action, the ship would be capsized in a very moderate sea-way. He further emphasizes the statement that the ships of the Admiral class in the English navy, if similarly treated, would also capsize under the same conditions, and he appears to be surprised at the admission having been made. The fact is that there has never been any assertion that the Admiral class would be safe against capsizing independently of assistance given to the armour-belted portions by the unarmoured structure situated above. On the contrary, from the first, in the design of these ships, it was recognized that their stability, in the sense of their power to resist being capsized, if inclined to even moderate angles of inclination, was not guaranteed by the armour belts. In this respect they were in identically the same position as all other armoured ships with shallow water-line belts and isolated armored batteries placed high above water.

What has been said respecting the Admiral class is this: If the unarmoured ends above the protective deck were completely thrown open to the sea, then the initial stability (that is to say, the stiffness of the ships or their power to resist small inclinations from the upright) would still be guaranteed by the central armoured portions. So fully did we appreciate the fact that the life of the ship in action (as determined by her power to resist large inclinations) depends greatly upon the assistance given by the unarmoured superstructures to the armour-belted parts, that we were careful to make the structural arrangements of the superstructures above the belts such that they could bear a very considerable amount of riddling and damage from shot and shell without ceasing to contribute in the most important degree to the buoyancy and stability.

There are double cellular sides between the belt and upper decks; the main bulkheads are carried up high above water; hatches and openings are trunked up and protected by coffer-dams. In short, every possible precaution is taken to subdivide into compartments, and thus limit the spaces to which water can find access when the outer sides are penetrated or shattered, as well as to facilitate the work of stopping temporarily shot-holes in the sides.

Now, without in the least intending to discredit the work of the French designers, I have to state that no corresponding or equal precautions have been taken in the portions of their ships lying above the belt-decks. And the absence of these features in the French ships is a great relative advantage to the English ships. Of course there is nothing to hinder the French from imitating our practice, but they are content to take the risks involved in a simpler construction, and in so doing they show their practical disbelief in the doctrine of armour-protected stability. I am aware that some eminent authorities do not concur with this view, and maintain that stability and buoyancy should be guaranteed by armour. To this point I will revert hereafter, but for the present I am content to say that, as between the French ships and the Admiral class, the most serious risks of damage by gun-fire in action are of the same kind, and, practically, are not affected by the shortening of the armour-belts in the English ships.

Next I would refer to the differences which are undoubtedly involved in shortening the belts of the English ships. In the first place, by dispensing with the side armour towards the extremities, a very considerable saving is effected in the weight and the cost of the armor fitted to the ships. Mr. Barnaby has recently given an illustration of this, where a ship, in other respects unchanged, has to be increased from 10,000 to 11,000 tons in displacement in order to carry the shallow armour belt to the ends. In the Collingwood herself quite as large a proportionate increase of size would be involved in having a thick armour belt from stem to stern. This saving in weight and cost of armour might, of course, be purchased too dearly, if dispensing with the armour involved possibly fatal risks to the ship. However the result may be attained, there is universal agreement that a ship-of-war should have her buoyancy, stability, and trim guaranteed as far as possible against the effects of damage in action. Now, in the Admiral class this matter was very carefully investigated before the design was approved. In order to prevent derangement of the trim of the vessels by penetration of the light sides above the protective deck at one end, arrangements were made in the design by means of which water can be introduced into the spaces occupied by coal-bunkers, &c., before the ships go into action.

The extent to which water may be introduced is a matter over which the captain would necessarily have control. But even if the whole of the unoccupied spaces were filled with water the increase in draught would not exceed 14 to 18 inches, and the loss in speed would not exceed half a knot. If only the coal-bunkers were flooded as a preliminary to action, the chance of any serious disturbance of trim, and consequent loss of maneuvering power or speed by damage to the light sides above the protective deck and near the water, would be very small, and the "sinkage" of the vessel would be decreased considerably. But taking the extreme case with the ends completely filled and a sinkage of 14 to 18 inches, a ship of the Admiral class would go into action with practically her full speed available, and with her ends so protected by under-water deck and the water admitted above that deck, that damage to the thin sides by shot or shell penetrating at or near the water-line would not produce changes of trim or alterations of draught to any greater extent than would be produced if the armour belt had been carried to the stem and stern. Nor would the admission of water into the ends render the vessel unstable.

It has been urged that the sinkage due to filling the tank ends with water is a disadvantage, because it brings the upper edge of the belt armour in the Admiral class about

14 to 18 inches nearer the water than the upper edge of the belts of the French ships. If the greatest danger of the ships was to be measured by the smallness of their "reserve" of "armour-protected buoyancy" (that is to say, by the buoyancy of the part of the ship lying above her fighting water-line and below the belt-deck), then the Admiral class would not compare favorably with the fully-belted French ships. But I have already explained that this is not the true measure of the greatest danger arising from the effects of gun-fire, and that it would be a mistake to assume that in either the French or the English ships the armour-belted portions of the vessels guarantee their safety when damaged in action.

As between the Admiral class and the central-citadel ships of the Inflexible type there is a difference in this respect which has been much commented upon. When the ends of the citadel ships are filled with water the armored wall of the citadel still remains several feet above water; whereas in the Admiral class, the top of the belt under similar conditions is very near the water-level. All that need be said on this point is that, notwithstanding the greater height of the armoured wall above water, the citadel ships have practically no greater guarantee of safety against capsizing by means of armour-protected stability than the Admiral class. In both classes the armoured portions require the assistance of the unarmored to secure such a range and amount of stability as shall effectually guarantee their security when damaged in action. And, as has been stated above, this condition is true of all armour-clads with narrow armor belts.

One other objection to the shortened belts yet remains to be considered.

It is urged that when the thin ends are broken through or damaged by shot or shell, jagged or protruding holes will be formed in the plating near the water-line, and then if the ships are driven at speed, the water will flow into the holes in large quantities, and produce serious changes of trim and loss of speed. In support of this contention, reference is made to the published reports of experiments made with the Inflexible's model about eight years ago. It is impossible to discuss the matter fully, and I must, therefore, content myself with a statement of my opinion, formed after a careful personal observation of these model experiments. First, it cannot be shown from the experiments that the presence of a shallow belt of armour reaching two to three feet above the still-water line would make any sensible difference in the dangers arising from the circumstances described. Holes in the thin sides above this belt would admit water in large quantities on the belt deck when the vessel was under way, and if it could flow along that deck changes of trim and other disagreeable consequences would result. Secondly, it is certain that the numerous bulkheads and partitions, coffer-dams, &c., built above the belt-deck level in the Admiral class for the very purpose of limiting the flow of entering water would greatly decrease any tendency to check the speed or change the trim. Whether the belt be short or long, it is evident that gaping holes low down in the light sides will make it prudent for a captain to slow down somewhat if he wishes to keep the water out as much as possible. But between such prudence and the danger of disaster there is a wide gulf.

Summing up the foregoing statements, I desire to record my opinion, based upon complete personal knowledge of every detail in the calculations and designs for the Admiral class, that the disposition of the belt armour (in association with the protective decks and cellular sides, water-tight subdivision, &c., existing in the unarmoured portions of the vessels situated above the protective decks) is such that the buoyancy, stability, trim, speed, and maneuvering capabilities are well guaranteed against extensive damage from shot and shell fire in action. And, further, that in these particulars the Admiral class are capable of meeting, at least on equal terms, their contemporary ships in the French navy.

I must add that I am not here instituting any comparison between the "fighting efficiencies" of the ships of the two fleets; nor have I space in this letter to do so. Opinions have differed, and will probably always differ, as to the relative importance of the different qualities which go to make up fighting efficiency. There is no simple formula admitting of general application which enables the comparative fighting values of war-ships to be appraised. As the conditions of naval warfare change and war material is developed, so the balance of qualities in ship designing has to be readjusted, and estimates of the fighting powers of existing ship have to be revised. And, further, different designers, working simultaneously, distribute the displacement, which is their sum total of capital to work upon, according to their own judgments of what is wisest and best for the particular conditions which the ships built from those designs have to fulfill. The designer who has the larger displacement to work upon has the better opportunity of producing a more powerful ship; but it by no means follows that he will secure so good a combination of qualities as a rival obtains on a smaller displacement. And hence I cannot but dissent from the doctrine that displacement tonnage is to be accepted as a fair measure of relative fighting efficiency, or that recent English ships are necessarily unable to fight recent French ships because they are of smaller displacement.

In the preceding remarks I have been careful to confine myself chiefly to the naval architect's side of the subject, as it would clearly be out of place for me to say much respecting the artillerist's side. But, having had the great advantage of knowing the views of some of the most experienced gun-makers and gunnery officers, and having studied carefully what has been written on the subject, I would venture to say a few words.

First, there seems, as was previously remarked, every reason for doubting, in the actual conditions of naval gunnery, whether it would be possible, not merely in a few minutes, but in a considerable time, to produce the wholesale destruction of the unarmored parts of modern war-ships which has been assumed in the condemnation of the Admiral class. If the Collingwood or one of her successors were simply treated as a moving target in a seaway for the Admiral Duperré or one of her consorts, this would be a most improbable result. But, remembering that the Collingwood would herself be delivering heavy blows in return for those received, the chances of her disablement would necessarily be decreased. Secondly, it does not seem at all evident that the introduction of rapid-fire guns has such an important influence on the question of shortened belts as some writers have supposed. So far as machine-guns are concerned, I well remember at the board meeting which decided to approve the building of the Collingwood the possible effects of machine-gun fire were discussed at some length, both in reference to the adoption of the barbette system and to the system of hull protection. The rapid-firing gun which has since been introduced is now a formidable weapon; but it may be questioned whether its effects upon the unarmoured portions of modern war-ships would be so serious as those resulting from the shell-fire of heavier guns, and therefore it cannot, with certainty, be concluded that it would be advantageous to make arrangements for keeping out the projectiles from the rapid-firing guns now in use at the ends of the Admiral class. More especially is this true when it is considered that already rapid-fire guns of much larger caliber and greater power than the 6-pounder and 9-pounder are being made. To these guns 3 inches of steel would be practically no better defence than the existing thin sides, and the real defence lies in the strong protective deck. Shell-fire from heavier guns will probably be found the best form of attack against the unarmoured or lightly-armoured portions of battle-ships, epecially now that the use of steel shells with thin walls and large bursting charges is being so rapidly developed.

I would again say that on this side of the subject I do not profess to speak with authority, and it is undoubted that great differences of opinion prevail; but it must not be forgotten that the Board of Admiralty, by its recent decision announced in the House of Commons, has reaffirmed the opinion that from the artillerist's point of view the existing disposition of the armour in the Admiral class is satisfactory. This has been done after the attention of the board and the public has been most strongly directed to the supposed dangers incidental to the rapid destruction of the light superstructures lying above the under-water decks of the Admiral class. It would be folly to suppose that in such a matter any merely personal considerations would prevent the board from authorizing a change which was proved to be necessary or advantageous. With respect to the possibility of making experiments which should determine the points at issue, I would only say that considerable difficulties must necessarily arise in endeavoring to represent the conditions of an actual fight; but in view of the diametrically opposite views which have been expressed as to the effect of gun-fire upon cellular structures, it would certainly be advantageous if some scheme of the kind could be arranged.

There still remains to be considered the question of the uses of armour in future war-ships. This letter has already extended to too great a length to permit of any attempt at a full discussion. It will be admitted by all who are interested in the questions of naval design that an inquiry into the matter is urgently needed, even if it leads only to a temporary solution of the problem, in view of the present means of offense and defense.

Armour, by which term I understand not merely vertical armour, but oblique or horizontal armour, is regarded in different ways by different authorities. For example, I understand Sir Edward Reed to maintain that side armour should be fitted in the form of a water-line belt, extending over a very considerable portion of the length, and that such armor, in association with a strong protective deck, and armoured erections for gun-stations, &c., should secure the buoyancy, trim, and stability of the vessel. At the other extreme we have the view expressed in the design of the grand Italian vessels of the Italia class. In them the hull armour is only used for the purpose of assisting the cellular hull subdivisions in protecting buoyancy, stability, and trim, taking the form of a thick protective deck, which is wholly under water, and above which comes a minutely subdivided region, which Signor Brin and his colleagues consider sufficient defense against gun-fire.

In these Italian vessels the only thick armour is used to protect the gun-stations, the pilot-tower, and the communications from those important parts to the magazines and spaces below the protective deck. The strong deck, besides forming a base of the cellular subdivision, is, of course, a defense to the vital parts of the ship lying below it.

Between these two types of ships come the Admiral class of the English navy and the belted vessels of the French navy, whose resemblances and differences have been described above.

In addition, there are not a few authorities who maintain that the development of the swift torpedo cruiser, or the swift protected cruiser, makes the continued use of armour at least questionable, seeing that to attempt to protect ships by thick armour either on decks or sides and to secure high speeds and heavy armaments involves the construction of large and expensive vessels, which are necessarily exposed to enormous risks in action from forms of under-water attack, against which their armour is no defence. In view of such differences of opinion and of the heated controversies which have arisen therefrom, the time seems certainly to have arrived when some competent body should be assembled by the admiralty for the purpose of considering the designs of our war ships, and enabling our constructors to proceed with greater assurance than they can at present. Questions affecting the efficiency of the royal navy clearly ought not to be decided except in the most calm and dispassionate manner. The work done by the Committee on Designs for Ships of War fourteen years ago was valuable and has had important results. What is now wanted, I venture to think, is a still wider inquiry into the condition of the navy, and one of the branches of that inquiry which will require the most careful treatment is embraced in the question, "What are the uses of armour in modern war-ships?"

My own opinion, reached after very careful study of the subject, is that very serious limitations have to be accepted in the disposition and general efficiency of the armaments, if the principle of protecting the stability at considerable angles of inclination by means of thick armour is accepted, the size and cost of the ships being kept within reasonable limits. There is no difficulty, of course, apart from considerations of size and cost, in fulfilling the condition of armor-protected stability; but it may be doubted whether the results could prove satisfactory, especially when the risks from under-water attacks, as well as from gun-fire, are borne in mind, and the fact is recognized that even the thickest armour carried or contemplated is not proof against existing guns. No vessel can fight without running risks. It is by no means certain, however, that the greater risks to be faced are those arising from damage to the sides in the region of the water-line and consequent loss of stability. So far as I have been able to judge it appears possible to produce a better fighting machine for a given cost by abandoning the idea of protecting stability, buoyancy, and trim entirely by thick armour, and by the acceptance of the principle that unarmoured but specially constructed superstructures shall be trusted as contributories to the flotation and stability. Thick vertical side armour, even over a portion of the length, appears to be by no means a necessary condition to an effective guarantee of the life and manageability of a ship when damaged in action; and it seems extremely probable that in future the great distinction between battle-ships and protected ships will not be found in the nature of their hull protection in the region of the water-line, but in the use of thick armour over the stations of the heavy guns in battle-ships.

The decisions as to future designs of our battle-ships is a momentous one. It can only be reached by the consideration of the relative advantages and disadvantages of alternative proposals. It cannot be dissociated from considerations of cost for a single ship.

On all grounds, therefore, it is to be hoped that a full and impartial inquiry will be authorized without delay, for it may be assumed that, however opinions differ, there is the common desire to secure for the British navy the best types of ships and a sufficient number to insure our maritime supremacy.

I am, sir, your obedient servant,

W. H. WHITE.

ELSWICK WORKS, *March* 26.

The following reply by Sir Edward Reed appeared in the Times of April 8, 1885, the omitted portions being personal allusions which have very little bearing upon the discussion, and which are of no interest to a professional reader outside of England:

It is not Mr. White's fault but his misfortune that he is compelled to admit the perfect correctness of the main charge which I have brought against these six ships, viz., that they have been so constructed and have been so stripped of armour protection that their armour, even when intact and untouched, is wholly insufficient to prevent them from capsizing in battle. Mr. White expends a good deal of labor in attempting to show that their unarmoured parts would have a better chance of keeping the ships upright and afloat than I credit them with, which is a secondary although an important question; but he frankly admits that these six ships of the Admiral type are, and are admitted to be, so built that their "stability in the sense of the power to resist being capsized if inclined to even moderate angles of inclination is not guaranteed by their armour belts."

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I have no doubt it would suit the purposes of all those who are or who have been responsible for those ships if I were to allow myself to be drawn, in connection with this question, away from the essential points just adverted to into a controversy upon the efforts made by the Admiralty to give to these ships, which have been denied a reasonable amount of armour protection, such relief from the grave dangers thus incurred as thin sheet compartments, coffer-dams, coals, patent fuel, stores, &c., can afford. (Cork is what was at first relied upon in this connection, but we hear no more of it now.) But I do not intend to be drawn aside from my demand for properly armoured ships of the first class by any references to these devices, and for a very simple reason, viz, all such devices, whether their value be great or small, are in no sense special to armoured ships; on the contrary they are common to all ships, and are more especially applied to ships which are unable to carry armour. The application of these devices to ships stripped of armour does not make them armoured ships, any more than it makes a simple cruiser or other ordinary unarmoured vessel an armoured ship; and what I desire, and what I confidentially rely upon the country demanding before long, is the construction of a few line-of-battle ships made reasonably safe by armour, in lieu of the present ships which, while called armoured ships, in reality depend upon their thin unarmoured parts for their ability to keep upright and afloat. Besides, I do not believe in these devices for ships intended for close fighting. I even believe them likely, in not a few cases, to add to their danger rather than to their safety. If, for example, a raking shot or shell should let the sea into the compartments on one side of the ship, while those on the other side remain intact and buoyant, this very buoyancy upon the uninjured side of the ship would help to capsize her

Mr. White says that no vessel can fight without running risks, and thinks that thick, vertical, side armour, even over a portion of the ship's length, is not a necessary guarantee of the life of a ship. Well, sir, we are all at liberty to think, or not think, what we please, so far as our sense and judgment will allow us; but Mr. White, like all other depreciators of side armour, fails utterly to show us what else there is which can be relied upon to keep shell out of a ship, or what can be done to prevent shell that burst inside a ship from spreading destruction all around. He refers us to no experiments to show that the thin plate divisions, and coffer-dams, and like devices, will prove of any avail for the purpose proposed. In the absence of any such experiments, he tell us, as others have told us, that Signor Brin and colleagues in the Italian Admiralty consider "a minutely subdivided region" at and below the water-line "sufficient defense against gun-fire." But I do not think Signor Brin believes anything of the kind; what he believes is that the Italian Government cannot afford to build a fleet of properly armored line-of-battle ships for hard and close fighting, and that, looking at their limited resources, a few excessively fast ships, with armour here and there to protect particular parts, and with ample capabilities of retreat to a safe distance, will best serve their purpose. I do not say that he is wrong, and I certainly admire the skill which he has displayed in carrying out his well-definded object. But that object is totally different from ours, and our naval habits, our traditions, our national spirit, the very blood that flows in our veins prevent such an object from ever becoming ours.

Mr. White all through his letter, in common with some of his late colleagues at the Admiralty, thinks and speaks as if naval warfare were henceforth to be chiefly a matter of dodging, getting chance shots, and keeping out of the enemy's way; and this may be more or less true of contests between unarmoured vessels. But why is not the line-of-battle ship Collingwood to be supposed to steam straight up to the enemy, I should like to know; and if she does, what is to prevent the enemy from pouring a raking fire through her bow, and ripping up at once, even with a single shell, every compartment between the stem and the transverse armoured bulkhead?

It distresses me beyond measure to see our ships constructed so as to impose upon them the most terrible penalties whenever their commanders dare, as dare they ever have, and dare they ever will, to close with their foe and try conclusions with him. Why, sir, it has been my painful duty over and over again to hear foreign officers entreat me to use all my influence against the adoption in their navy of ships with so little armoured surface as ours. On one occasion the Collingwood herself was imposed upon them as a model to be imitated, and I was besought to give them a safer and better ship. "How could I ever steam up to my enemy with any confidence," said one of the officers concerned, "with such a ship as that under my feet?"

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Mr. White cooly tells us that the Collingwood, with 500 tons of water logging her ends to a depth of 7 or 8 feet, will not be much worse off than a ship whose armoured deck stands 2½ or 3 feet above the water's surface, and his reason is that even above this latter deck the water would flow in when the ship was driving ahead with an injured bow. Well, sir, I will only say that sailors of experience see a very great difference between the two cases, and I can but regard such theorizings as very unfortunate basis for the designs of Her Majesty's ships.

I have said that Mr. White's assumptions as to the immunity of the above water compartments and coffer-dams from widespread injury by shell-fire rest upon no experimental data; I go on to say that such data as we have to my mind point very much the other way. The Huascar was not an unarmoured vessel, and such shell as penetrated her had first to pass through some thin armour and wood backing; yet after the Cochrane and Blanco Encaloda had defeated her she presented internally abundant evidence of the general destruction which shell-fire produces. An officer of the Cochrane, who was the first person sent on board by the captors, in a letter to me written soon afterwards, said:

"It requires seeing to believe the destruction done. * * * We had to climb over heaps, table high, of *débris* and dead and wounded. * * * We fired 45 Palliser shell, and the engineers who were on board say that every shell, or nearly so, must have struck, and that every one that struck burst on board, doing awful destruction."

Speaking of the injury which the Cochrane received from a single shell of the Huascar, he said:

"It passed through the upper works at commander's cabin, breaking fore and aft bulkhead of cabins, breaking skylight above wardroom, thwartship bulkhead of wood, passed on, cut in two a 5-inch iron pillar, through a storeroom, struck armour, plate, glanced off, passing through plating of embrasure-closet at corner, finishing at after gunport, and went overboard. This shell passed in at starboard part of stern and terminated at after battery port on port side, which is finished with the wide angle-iron, carrying out a part of the angle-iron in its flight."

This was a shell of moderate size from a moderate gun, but it is obvious that it would have made short work of penetrating those very thin sheets of steel which constitute the compartments, coffer-dams, &c., upon the resistance of which, to my extreme surprise, those responsible for the power and safety of our fleets seem so ready to place their main dependence.

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For resistance to rams and torpedoes, and for the limitation of the injuries to be effected by them, as much cellular subdivision as possible should be supplied, but as against shot and shell, subdivision by their sheet-steel is no guarantee whatever of safety in any ship, least of all in line-of-battle ships, which must be prepared for fighting at close quarters.

I must now ask for space to remark upon a few minor points in Mr. White's letter. He seems to consider that the scant armour of the Admiral class is somehow associated with the placing of the large partly-protected guns of these ships in separate positions, "in order to reduce the risks of complete disablement of the principal armament by one or two lucky shots, which may happen when the heavy guns are concentrated on a single citadel or battery." Suffice it to reply that, in the proposed new designs of the Admiralty ships now before Parliament, which have almost equally scant partial belts of armour, the guns are nevertheless concentrated in a single battery.

Again, Mr. White says the Admiralty have declined to adopt my advice to protect the Admiral class in certain unarmored parts with 3-inch plating, and declares that such plating would practically be no better defense against rapid-fire guns than existing thin sides; but has he forgotten the fact that my suggestion has been adopted in the new designs for the protection of the battery of 6-inch guns, although it is perversely withheld from those parts of the ship in which it might assist in some degree in prolonging the ship's ability to float and to resist capsizing forces?

Mr. White makes one very singular statement. He takes exception to my claim-ing for the Inflexible type of ship, on account of their armoured citadel, a much better chance of retaining stability in battle than the Admiral type possesses, because, he says, "in both classes the armoured portions require the assistance of the unarmoured to secure such a range and amount of stability as shall effectually guarantee their security when damaged in action." The fair inference to be drawn from this would be that where the principle long ago laid down by me, and supported by Mr. Barnaby in the words previously quoted, is once departed from, the danger must in all cases be so great as to exclude all distinctions of more or less risk. Mr. White can hardly mean this; but if he does not, then on what grounds are we told that a ship which has no armour at all left above water at an inclination, say, of 6° or 8°, is no worse off than a ship which at those angles, and at still greater ones, has a water-tight citadel over 100 feet long to help hold her up?

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I am not at all disposed to enter into a discussion as to the relative stabilities of the English and French ships under various conditions. The French ships have armoured belts 2½ to 3 feet above water from end to end. That fact, other things being presumed equal, gives them an immense advantage over our ships, which, in battle trim, have belts scarcely more than a foot wide above water, and for less than half their length. It is quite possible that the French constructors may have given their ships less initial stability than ours; from such information as I possess I believe they have; but in so far as the ship below the armor deck and the action of shot and shell upon that part of her are concerned, whatever stability they start with in battle they will retain until their armour is pierced; whereas our ships may have a large proportion of theirs taken from them without their armor being pierced, and their armored decks are then less than half the height of those of the French ships above water.

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I will add that I doubt if the French ships are dealt fairly by at Whitehall. I lately heard a good deal of the extreme taper of their armour belts at the bow, and the Amiral Duperré was always quoted in instance of this. It is true that this ship's armour does taper from 55 centimeters amidships to 25 centimeters at the stem, but she stands almost alone among recent important ships in this respect, as the following figures will show:

Name.	Thickness of armor amidship.	Thickness of armor at bows.
	Centimeters.	*Centimeters.*
Amiral Baudin	55	40
Formidable	55	40
Hoche	45	40
Magenta	45	40
Marceau	45	40
Caiman	50	35
Fulminant	33	25
Furieuse	50	32
Indomptable	50	37
Requin	50	40
Terrible	50	37

A friend writes me: Comparing the Amiral Duperré with the Amiral Baudin, Devastation, Formidable, and Foudroyant, which are ships of about her size, the following peculiarities are observable. The Duperré is about 3 feet narrower than the other ships mentioned, and has fully 15 inches less metacentric height. She is also slightly deeper in proportion to her breadth than the other ships.

As narrowness, small metacentric height, and excessive depth all tend to reduce stability, it would appear that the Admiralty office has, as I supposed, been careful to select a vessel not unfavorable to their purpose. But however this may be, it is no business of mine to defend the French ships in the details of their stability, nor even to defend them at all; and as a matter of fact, the French Admiralty, although stopping far short of ours, has, in my opinion, gone much too far in the direction of reducing the armoured stability at considerable angles of inclination. But their falling into one error is no justification for our falling into a much greater one, and deliberately repeating it in every ship we lay down. In this connection I will only add that the experiments performed at our Admiralty on models must be viewed with great distrust for a reason not yet named. They deal only so far as I am acquainted with them, with models set oscillating or rolling by waves or otherwise. But the danger thus dealt with is a secondary one; the primary one is that due to "list" or prolonged inclination to one side. What sort of protection against the danger of capsizing from this cause can be possessed by a ship the entire armour on each side of which becomes immersed even in smooth water when the ship is inclined a couple of degrees only, and which then has no side left to immerse, save such as single shells can blow into holes 10 by 4 feet?

It is to be observed that although Mr. White does not venture to join the only other apologist for these deficiently armoured ships in stating that india-rubber umbrella shot-stoppers are to be employed for their preservation in battle, he does go so far as to tell us that the spaces into which water would enter when the unarmoured parts have been penetrated, have been subdivided, "to facilitate the work of stopping temporarily shot-holes in the sides," and I know independently that a good deal of reliance is placed at the Admiralty upon the presumed ability to stop such holes as they are made. But the whole thing is a delusion. The officer of the Cochrane, before quoted, said—

"I wish to state that shot-plugs are out of the question after or at such a fight. They are entirely useless. Not a hole was either round, square, or oval, but different shapes, ragged, jagged, and torn, the inside parts and half-inch plating being torn in ribands; some of the holes inside are as large as 4 by 3 feet, and of all shapes. There are many shot-plugs on board here, all sizes, conical shapes and long, but they are of no use whatever."

Mr. White's letter invites many other comments, but I have said enough to show that it in no way changes my view of the question of armour-plated line-of-battle ships. In so far as it advocates a further abandonment of armour and a further resort to doubtful devices in lieu thereof, it is already answered by anticipation by the Admiralty itself. Until I wrote my recent letters to you, our Admiralty thought as Mr. White still thinks, and tended as he still tends. In the case of all our recent cruisers but two, they had abolished side armour altogether. To my public appeal for armour-belted cruisers they have, however, responded, and are about to order six of such ships. So far, so good. We ought to be grateful for this concession to a most reasonable demand. I wish these cruisers were to be faster, much faster, but in Admiralty matters the country must be thankful for small mercies.

It only remains for me to note with satisfaction one or two of the points upon which Mr. White is in agreement with myself. He admits that it "would certainly be advantageous" to carry out those experiments which I regard the Admiralty as afraid to make, viz., experiments to test the effect of gun-fire upon the subdivided but unarmoured parts of ships.

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It may be taken for what it is worth, but I declare that the abandonment of armour has not at all been forced upon us by unavoidable circumstances, nor is it from any intrinsic necessity that we go on refusing to provide our ships with torpedo defense. On not immoderate dimensions, at not immoderate cost, ships might be built, still practically invulnerable to gun, ram, and torpedo alike, ships which could dispose of the Admiral class of ships more quickly and certainly than she could dispose of the feeblest antagonist that she is likely to encounter. But in order to produce such ships we must revive the now abandoned principle that armour and armour alone can save from destruction those ships whose business it is to drive our future enemies from the European seas and lock them up in their own ports.

The Committee on Designs of 1872, previously alluded to, contained sixteen members, of whom six were naval officers. Two of those members, Admiral George Elliot, R. N., and Rear-Admiral A. P. Ryder, R. N., dissented so far from their colleagues that they could not sign the report, and accordingly they submitted a very able minority report embodying their views.

The first of the "general principles" laid down in their report is as follows:

> (1) That it is of the last importance that the modifications in existing types of men of war which the committee have been invited to suggest should be calculated not merely to effectually meet the necessities of naval warfare now and in the immediate future, but in full view of the probable necessities of naval warfare in the more remote future.

It must be a source of satisfaction to these gallant officers to observe in some designs of the present day a confirmation of their forecast in many particulars.

The following extracts from a letter bearing upon the present controversy, by Admiral Elliott, appeared in The Times of April 24, 1885, and contain the pith of his oft-quoted arguments:

> My first impresssion on reading these letters in The Times is one of disappointment that the point at issue between these two experts has not been more closely confined to the comparative merits of side armour *versus* cellular deck armour, but that their attention has been directed to this feature of design only as connected with a particular type of ship, namely, the Collingwood, which vessel is a hybrid, or cross between the two systems of protection to buoyancy, and therefore not truly representative of either. Mr. White's defence of the unarmoured ends of the Collingwood is so far unsatisfactory that it treats of a very imperfect development of the cellular-deck mode of protection, and therefore he is not an exponent of the real merits of this system.
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> I am quite aware that the main point at issue between these two distinguished naval architects has been more closely confined to the question of stability than to that of flotation as displayed in the design of the Collingwood, and in this scientific view of the case I do not feel competent to offer any opinion, except to point out that the cellular-deck principle *per se* does not involve any such danger as regards stability as is produced by the top weight of a central citadel. Mr. White acknowledges that this top weight will capsize his ship if deprived of the buoyancy afforded by the unarmored ends, and on this danger point Sir Edward Reeds fixes his sharpest weapon of attack.
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> The great issue at stake is how the weights available for the protection of buoyancy and for gun defence are to be distributed to the best advantage for defensive purposes, and in order to discuss Sir Edward Reed's opinions in a concise form I wil deal with the question solely as concerning the use of side armour of less than 12 inches, beyond which limit of thickness I will, for the sake of argument, admit its practical advantages; and, looking to the demand for increased speed and coal-carrying capacity, it does not appear probable that if combined with adequate gun protection and if of sufficient depth, an all-round belt of thicker than 10 inches can be carried by any vessels of war except those of much greater displacemsnt than the Collingwood class. I feel justified, however, in discussing the question on this basis, because Sir Edward Reed includes in his category of approved armoured ships our recent belted cruisers, having a narrow belt of 10 inches maximum thickness, and takes credit for having

induced the Admiralty to abandon their original intention of cellular-deck water-line protection in this class of war-ship in favor of this thin armour belt.

The relative value of these two systems of water-line protection, namely, an all-round belt *versus* a raft body, must not only be ruled by the displacement decided upon for each class of vessel and by the power of the gun which has to be encountered, but by such tactical expedients as can be resorted to in battle, as being those best suited to the known offensive and defensive properties of the combatants.

Looking at this disputed question entirely from the point of view of an artillerist and a practical seaman, I can perceive very great tactical advantages to be obtained by the adoption of the mode of protection proposed as a substitute for obsolete armour, and I view with much regret the one-sidedness of the conclusions arrived at by the opponents of this system, and the disparaging terms in which it is sought to turn it into ridicule, such as "doubtful devices" and "useless contrivances," &c., because they indicate prejudice and a want of mature consideration of the incidents of naval battles. I cannot, also, help observing that while, on the one side prophesying the most fatal consequcnces to ensue from what is called "stripping ships of armour," on the other side no admission is made of the disastrous results which must follow from placing reliance on such a delusive defensive agency as an armour-plate known to be penetrable by guns certain to be encountered; and in order to support this theory, we are called upon to believe that gunners will be so excited in action or so unskillful that in no case will they hit the large object aimed at, namely, the water-line of an adversary passing even at close quarters on their beam, but I shall refer to this feature of assumed impunity hereafter.

Sir Edward Reed's comparative remarks on the effect of shot holes as between the two systems of defence are of the same one-sided character, notwithstanding the evidence of the fractured condition of armour-plates subjected to experimental firing; and it is almost apparent that in decrying the one mode of protection he has lost sight of the fact that a 10-inch armor-plate is all that will stand between the life and death of a ship, that is to say, between one well-directed shell and the magazines and boilers, which plate can be easily penetrated and smashed up by the guns which similar vessels will assuredly carry if so invited. Also, in referring to the baneful effects of raking fire and shell explosion inboard, the assumed inferiority is misplaced because one prominent advantage of the cellular-deck system is that by economizing weight at the water-line it enables the bow and stern to be armor-plated—a matter of the highest tactical importance as a defense against raking fire, which is unobtainable in a belted ship of the same displacement, at least without entailing a considerable reduction of the thickness of armour on the belt. This feature of end-on defence is not only an essential element of safety, but must prove most effective as enabling a combatant to close his adversary at an advantage, and enforce the bow-to-bow ram encounter, or compel him to resort to a stern fight, or otherwise to pass him at such close quarters as will insure direct hits and depressed fire at the water-line belt, and by these tactics the opportunities for riddling the raft body will be few and far between.

I may also express the opinion that for repairing damages in a raft-bodied ship at the water-line far more efficacious means can be resorted to than the ordinary shot plugs, and that the use of cork bags for closing shot holes in the coffer-dam sides, if they are open at the top, is far from being an unreasonable or "stupid contrivance," as it is called, considering that, as a general rule, the perforations through thin plating would not be ragged or extensive. Sir Edward Reed's wise suggestion to make the outer skin of the coffer-dam of 2-inch steel plates would render machine-gun fire of little avail. The injurious effects of shell fire would, I reckon, be far more fatal if the projectile exploded in passing through the 10-inch belt than if it burst at some distance inboard after penetrating thin plating. I think it will be admitted without dispute that this feature of design must be governed to a great extent by tactical considerations, the object sought for being to secure out of a given weight of steel the greatest amount of fighting vitality consistent with the power of maneuvering available between skillful antagonists. This view of the case is especially applicable to single actions at sea, when a clever tactician will select his mode of fighting according to the offensive and defensive properties known to be possessed by his opponent, and in this respect an armour-plated bow and stern will afford enormous advantages, both for attack and defense, if the plating is extended as high as the upper deck.

In fleet actions the ram and torpedo will require more attention than the gun attack, and that feature of battle introduces another disputed point, namely, the limit of size of ship; but that question is outside the scope of the present discussion, and I shall conclude my arguments by a strong expression of opinion that, as gunpowder has so completely mastered the pretensions of outside armor protection, the direction in which prudence leans towards defensive properties in future designs for ships of war is that of deflection rather than of direct resistance, and that in this respect science has not reached its utmost limit of invention.

The prevailing disposition to regulate the power of the gun by the size of the vessel is, I consider, a great mistake, seeing that the additional weight of a powerful gun is not inadmissible, even in such vessels as our belted cruisers, and looking to the strong inducement held out by the continued use of armour-plating, even of such moderate thickness as 10 inches. In the splendid steamers purchased from the mercantile marine, which are being armed with light guns only, one 25-ton gun would greatly add to their fighting power, but the cause of this omission may probably be found in the answer to the question, Where are the guns?

The following reply appeared in the Times of May 1, 1885:

SIR: The letter of Admiral Sir George Elliot * * * deals ably and candidly with a subject of such fundamental importance to our navy that I venture to offer a few observations upon it.

I am glad to see that the gallant admiral separates his case and the cellular or raft deck system from any connection with the Collingwood or Admiral type of ship, but I regret that he has treated my criticisms of that kind of ship just as if I had applied them in the abstract to the system which he advocates. This is not fair either to the gallant officer himself or to me, as will presently appear.

If Sir George Elliot will remove the cellular or raft deck question completely away from the very unsatisfactory and unpleasant region of Admiralty practice and let it be treated upon its merits, while I shall still have to respectfully submit to him some cautionary considerations, I shall also be prepared to make to him some very considerable concessions. One thing I should find it desirable to press upon him is the absolute necessity of giving closer attention to the provision of stability. He treats the subject mainly as a question of "buoyancy," and wisely so from his point of view; but "stability," or the power of resisting capsizing, comes first, and on this he declines to offer an opinion. Again, when the gallant officer speaks of a "raft" deck, I would point out that this may be a very different thing from a cellular deck. The characteristic of a raft is that it is usually formed of solid buoyant materials; you may make it of cellular steel if you please, but in that case wherever injury lets in water the steel so far ceases to be a raft which helps to float its load, and becomes a weight to help sink it. Now, cells formed of thin steel do not upon the face of the matter appear to be safe materials for a raft which is to be subject to the multitudinous fire of small guns and the explosions of shells of all sizes. It needs a very skillful artificer to build a safe floating raft of thin steel for such a purpose, especially when regard is had to the dangers of raking fire, against which bow and stern armour would not sufficiently provide.

Having expressed these cautions, I will go on to say that, in my opinion, the main idea of your gallant correspondent, which he has so long and so steadily developed, is nevertheless a sound one, and one which has a great future. I do not, of course, for a moment admit with him that the gun has yet mastered the armor. I believe the Dreadnought, though of old design, would still fight a good action against all ships now ready for sea, and have to fear only a very exceptional, and, therefore, either a very skillful or very fortunate shot. The recent Admiralty ships, where they are armoured, are practically proof against almost every gun afloat. Further, I have satisfied myself that if the existing restrictions imposed upon us by the absence of floating docks adapted to receive ships of great breadth were removed (these restrictions crippling us to a most unfortunate degree), and if certain professional conventionalities as to the forms of ships were set aside, it would be perfectly practicable to build war-ships no larger and no more costly than the Inflexible, with enough side armor more than a yard (3 feet) thick to preserve their stability, and at the same time made ram-proof and torpedo-proof. Meanwhile of all the vulnerable objects afloat, the recent guns themselves, by reason of their absurdly long and slender barrels, left fully exposed to all fire, are among the most vulnerable.

Still the raft-deck system has a wide field before it, and I am quite prepared to admit that I believe in its practicability and in its sufficient security for certain classes of vessels if properly carried out. This it has not yet been in any single instance. Even in the case of the great Italian ships as in our own, there are elements of weakness which would be fatal to the system in action, but which are *not* unavoidable. Allow me to assure Sir George Elliot that I have largely and closely studied this subject, and that my main objections to it are not objections of principle.

If the raft-deck system is to be adopted, it must, in my opinion, be carried out in a much fuller and more satisfactory manner than hitherto, and with the aid of arrangements which I have for a long time past seen the necessity of and been engaged upon.

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To my mind the Admiralty, while protecting certain parts and contents of their largest ships from injury from shell-fire, have made the fatal error of failing to protect the ship itself, which contains them all, from being too readily deprived of stability and made to capsize. The advocates of the alternative system must not repeat this error, or, if they do, they must not expect me to become their ally. On the other hand, if they will join me in despising what are merely specious elements of safety and in demanding those which are real, if they will insist that our principal and most costly ships at least shall be so constructed as to keep afloat and upright for a reasonable length of time in battle, in spite of any form of attack, so as to give their gallant crews a fair chance of achieving their objects, they will not find me averse to any improvement whatever. When a suitable opportunity offers I shall be happy to show to Admiral Sir George Elliot that he has not been alone in seeking to develop the cellular or raft deck system, and that it has, in fact, capabilities which possibly he himself may not yet have fully realized.

The same number of the Times contains a reply to Mr. Reed's letter of April 8, 1885, by Mr. White, mainly devoted to a refutation of certain charges of no interest to us, but containing the following paragraphs:

I must refer to the passage in which Sir Edward Reed quotes a description of the damage done to the Huascar in her action with the two Chilian iron-clads.

This description seems to me one of the best possible illustrations of a remark in my previous letter, that "the *mitraille* which is driven back into a ship when armour is penetrated is probably as destructive as any kind of projectile can be." Had the Huascar not had weak armor, but light sides only, the local injuries might have been less. The other case cited of a shell which entered the unarmoured stern of the Cochrane shows how little damage may be done when a projectile passes through thin plating. At the bombardment of Alexandria there were many such examples on board our ships, although it must be frankly admitted that the engagement is no sufficient indication of what shell-fire may do. A good deal of use has been made of the single case where a shell, in bursting, blew a hole 10 by 4 feet in the thin side-

> plating of the Superb. The case was quite exceptional, whether it be compared with the other hits on the same ship or with the injuries done to the unarmoured sides of other ships. Moreover, in that case exceptional injury is traceable to special structural arrangements at the embrasure near the battery port where the shell struck, These cases do not prove that the light unarmoured structures in the Admiral class are likely to be destroyed in such a rapid and wholesale manner as has been asserted. Nor, on the other hand, do they indicate conclusively what damage shell-fire may do in future actions. On these points, as I have before remarked, experiment might be made with advantage. But, on the other hand, there is good evidence that armour so thin as to be readily penetrable to many guns may be a serious danger, and that armour over the vital parts of ships should be strong if it is to be a real defense.
>
> * * * * * * *
>
> In matters of ship design the constructors of the navy are only the servants of the board, and, while they must take sole responsibility for professional work, the governing features in the designs are determined by higher authorities, among whom are officers of large experience, both as seamen and gunners. And it is certainly not the practice of the constructive department to intrude themselves or their advice into matters for which neither their training nor their experience fits them to give an opinion.
>
> * * * * * * *
>
> I make no attempt to be either a sailor or a gunner, but am content to seek information from the best authorities in both branches. As the result of this study of tactics and gunnery I have been led to the belief that the sea-fights of the future are not likely to be settled altogether or chiefly by the effects of gun-fire. This is not quite the same thing as Sir Edward Reed attributes to me when he says that "Mr. White thinks and speaks as if naval warfare henceforth were to be merely a matter of dodging, getting chance shots, and keeping out of an enemy's way."
>
> Nor do I think that the designers of the Italian war-ships will indorse the description of their views and intentions with which Sir Edward Reed has favored us in his letter and elsewhere. I have the honor of knowing his excellency Signor Brin (now minister of marine) and other members of the constructive corps of the Italian navy, and from their statements, including the powerful publication of Signor Brin "La Nostra Marina Militare," I have no hesitation in saying that in spending larger sums on single ships than have ever before been spent, the Italian authorities think, and are not alone in thinking, that they are producing the most powerful fighting ships afloat.

The most striking feature in the foregoing arguments is the high respect in which the Italian battle-ships are held by authoritative disputants, and the general admission of the correctness of the principles upon which those ships depend for protection to stability.

THE ITALIA.

(Plate I.)

The Italia was designed in 1878 by Signor Brin (inspector of naval architecture and marine engineering), to embody the conceptions of the energetic and sagacious Admiral St. Bon (then minister of marine), whose long study of the requirements of naval warfare and admirable exposition of its principles, as applied to Italian necessities in the remote future, led to a demand for battle-ships, pre-eminently independent on the high seas and capable of any voyage, with offensive powers and speed greater than that of any ship then building or thought of, capable of carrying many troops, and reasonably safe against submarine attacks.

To accomplish all this with practicable dimensions a new type had to be adopted, and many novelties introduced, among which may be mentioned the substitution of a protective deck with armored hatchways, in conjunction with the subdivision of the water-line space above it, into a well-considered cellular system for protection to stability, and the introduction of steel in the construction of the hull. The boldness of this stupendous experiment caused widespread astonishment, and now challenges the admiration of the world.

During construction there were no changes made in the hull, although the disposition of the armament and gun-armor was afterwards modified, and she was launched in 1880.

Principal dimensions.

Length between perpendiculars	feet	400⅓
Length over all	do	407
Molded breadth	do	72⅚
Extreme breadth	do	73⅚
Draft:		
Forward	do	25⅓
Aft	do	30⅓
Mean	do	27⅚
Displacement	tons	*13,632

The displacement increases 52.4 tons per inch of immersion at load water line.

Armament.—Four 16.9-inch 106-ton B. L. R., mounted in pairs, *en echelon* and *en barbette*, in central armored redoubt at a height of 33½ feet above load water-line and 13 feet above the spar-deck.—They have an elevation of 15° and a depression of 10°. With this depression they can strike a vessel's water-line at a distance of 180 feet, and with 12° of elevation they can strike a fort situated 1,476 feet above the water and distant 10,000 feet.—Eighteen 6-inch 4-ton B. L. R., mounted on Albini carriages; twelve on upper battery-deck, in broadside, four in superstructure before and abaft the redoubt, and two at the extremities on spar-deck, under cover.

The hull.—A double bottom, 3.28 feet deep, extends for 253 feet under all the machinery and boiler-space. The space between the inner skin of the double bottom and the armored deck is divided by longitudinal and transverse bulkheads into fifty-one water-tight compartments containing engines, boilers, coal, and ammunition. Forward and abaft the double bottom other bulkheads divide the the hold into eighteen more water-tight compartments, occupied by steering-gear, coal, water, provisions, ordnance, and general stores.

With a view to decreasing weight, while retaining longitudinal rigidity, an important modification of the bracket-plate system of framing

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[*] With the modifications introduced the displacement became 13,900 tons.

has been introduced. The bracket-plates which usually tie the angle-irons forming the transverse frames are suppressed, and the latter consist of two angle-irons only, the outer one being firmly secured to and separating the longitudinals, while the inner one is continuous from the vertical keel to the futtock, forming the framing of the top side, to which it is secured.

The longitudinals, of which there are nine on each side of the vertical keel, are duly lightened by holes which serve as man-holes, and are strengthened at their edges by angle-irons, to which the outer and inner skins are secured. The vertical keel and the fifth and ninth longitudinals on each side are water-tight, so that the double bottom is divided into four longitudinal alleys, which are subdivided transversely by water-tight bulkheads, so that the double bottom contains eighty-four separate compartments. There are several self-closing doors for communication, and little doors for ventilation in the inner skin. The longitudinals reach beyond the double bottom, and three of them extend all the way to the extremities.

Under the engines and boilers the transverse frames are strengthened where necessary by complete bracket-plates, and beyond the double bottom the transverse frames are of plates lightened by holes and stiffened by principal and reverse angle-irons.

The tranverse bulkheads in the double bottom are fastened to the plating by two angle-irons, and are stiffened by vertical angle-irons and horizontal T-irons, which add greatly to their rigidity. The longitudinal bulkheads are also strengthened by T-irons and well secured to the transverse bulkheads, care being taken to assure perfect joints everywhere.

The armored deck extends from stem to sternpost, dipping down forward to strengthen the ram, and aft to protect the steering-gear. At the ship's sides it extends 6 feet below the load water-line (the original) and has a round up of 3.5 feet amidships. It is composed of compound armor-plates, 2.7 inches thick, laid upon continuous deck-plates six-tenths of an inch thick, secured to the sides by intercostal plates and angle-irons, making a water-tight joint. This protection will be as good as 4 inches of wrought iron.

The smoke pipes have their bases protected by armor 16 inches thick, which rises 3½ feet above load water-line, and the ammunition hoist is a heavily armored tube extending from this deck to the redoubt.

Cellular protection.—The cellular structure above the armored deck or the space between it and the battery-deck, which is 5.2 inches above the water-line, is divided horizontally into two distinct upper and lower parts by a plate extending from stem to stern. This plate is 16 inches above load water-line, and the space between it and the armored deck is divided into one hundred water-tight compartments. Many of these compartments will be filled with coal, provisions, and other stores.

If almost all the bulkheads of this structure were pierced, and most of the compartments thus opened to the sea, the ship would sink a few inches only.

The cellular structure above this is built of continuous longitudinal water-tight bulkheads, strengthened at top and bottom by angle irons which tie them to the plating of the lower battery-deck, and to the horizontal dividing plate before mentioned. All joints are water-tight, the transverse bulkheads forming practically water-tight beams and adding greatly to the great strength of the structure. This upper cellular structure contains one hundred and fifty-four water-tight compartments.

About 3 feet from the sides of the ship are two wing-passages formed by water-tight bulkheads, following the contour of the sides and extending vertically from the lower battery-deck to the armored deck. These passages are subdivided by the transverse bulkheads, and are intended to be used as coffer-dams. By lifting the strakes which cover them on the lower battery-deck, they may be filled with canvas, oakum, &c., whenever a leak occurs.

The ram is of exceptional strength. A heavy central longitudinal bulkhead, three longitudinals, the armored deck, a horizontal bulkhead, and all the decks are strongly tied to the stem, which is a heavy piece of wrought-iron, weighing 20 tons, projecting $6\frac{1}{2}$ feet at a depth of $8\frac{3}{10}$ feet below load-water mark. The outer skin of the bow is doubled and through-bolted to the stem.

The decks.—Above the cellular space is the "lower battery" deck and above that the "upper battery" deck. Both are steel plated, high, spacious, well ventilated, and satisfying the requirements of habitability to an unprecedented extent, and they are capacious enough to carry a great many troops. Both will be used for quarters, store-rooms, hospitals, baths, &c., while twelve of the lighter guns of the main battery will be mounted on the upper, and the installment of torpedo tubes on the lower. The hawse pipes, capstans, bitts, &c., are on the upper, while the capstan engines are in a little compartment between the two.

These deck-spaces are subdivided by four transverse bulkheads only, which, together with three longitudinals, reach to the spar-deck.

The continuity of the spar-deck, plated with $\frac{1}{2}$-inch steel, is broken by the superstructure surrounding the armored redoubt and containing four of the 6-inch guns, two on each broadside.

The armored redoubt is supported by the ship's sides, and the seven bulkheads which form the engine-rooms and magazines. It is protected at the sides by compound armor 17 inches thick, inclined 24° from vertical, and at the top and bottom by heavy double steel plates riveted together.

Engines.—There are four separate, three-cylinder, vertical, inverted, direct-acting engines with surface condensers. In economical use the steam is admitted to one cylinder and expanded in the other two, but

Page 69, 3d column of table, "Coal Consumption," should be headed "Kilogrammes." And the comma in 3d and 4th columns should have been a decimal point. These columns may be read:

Pounds.	*English tons.*	
2.64	21.2	
2.64	11.8	
1.76	4.7	
1.98	1.8	(1,800 kilogs.)
1.98	.7	

at full power it is admitted to all three cylinders at once, and exhausts directly into the condensers.

Each engine develops 4,500 I. H. P., or 18,000 I. H. P. collectively; but this may be reduced to 450 I. H. P.

The engine-rooms are protected at the wings by coal bunkers, the bulkheads of which are 11½ feet from the sides.

If two of the engine-rooms were flooded, the volume of water admitted would be only 780 cubic meters, without allowing for the volume of the engines, and the ship would sink only 14 inches.

Boilers.—There are twenty-six elliptical, three-furnace, return fire-tube boilers in six separate water-tight compartments which can be entered only from the lower battery-deck. Each group has its own separate smoke-pipe, the fire-rooms are longitudinal and amidships, and each boiler can furnish steam to any of the four engines. Each group can be supplied with coal from the neighboring bunkers.

If two groups were disabled the horse-power would be diminished only one-third, and with 12,000 I. H. P. the speed would still be 15½ knots. Normal steam pressure, 60 pounds.

Coal capacity, endurance, performance.—The Italia can stow 2,180 tons of coal in the hold and wing-passages, besides 1,500 tons in the cellular structure, or 3,680 tons in all; but this 1,500 extra increases her draught about 3 feet.

Sixteen hundred tons is good for three months at reduced speeds. To pass from reduced speeds to the highest requires but a few minutes, and to pass from 13 knots to full speed only a few seconds.

Condition of engine.	I. H. P.	Estimated speed.	Coal consumption.		Endurance.			
			Per I. H. P. per hour.	Total per hour.	With 1,600 tons.	With 3,100 tons.	With 1,600 tons.	With 3,100 tons.
			kilos ~~Tons~~.	*Tons.*	*Hours.*	*Hours.*	*Miles.*	*Miles.*
All four engines:								
Full speed, working simple	18,000	17.6	1,200	21,600	74	143	1,258	2,440
Half-power, working simple	10,000	15.1	1,200	12,000	133	258	2,008	3,900
Working compound	6,000	12.7	800	4,800	333	646	4,233	8,202
The two after engines:								
Working compound	2,000	8.5	900	1,600	1,000	1,937	8,500	16,469
At most economical speed	800	6.5	900	720	2,222	4,305	14,440	27,986

The use of mechanical aids is extensive. The rudder works by steam, ashes are hoisted, weights handled, and the guns pointed by mechanical as well as manual power. The rudder-head does not enter the stern, but bears a yoke which is operated by pistons and rods moving in small cast iron cylinders inside the ship. Both hand and steam power can be used in steering. Each piston and rod is sufficient to hold and work the rudder alone.

The hull has a 3-inch sheathing of wood and zinc uncalked.

Weights, &c.—The weight of hull at launching was 3,800 tons, adding to which the deck-plating, internal subdivision, cement, &c., made it 4,500 tons, or only 32 per cent. of displacement.

The hull, including redoubt, weighs 37 per cent. of displacement, which is quite small in view of the fact that she has three complete steel decks besides the armored deck, high freeboard, and exceptionally numerous compartments.

The total weight of machinery, including filled boilers, is 2,400 tons, or 298 pounds per I. H. P.

The Lepanto, a sister ship, was laid down subsequent to the Italia, launched in 1883, and embodies the same features, except that the displacement remains 13,550 tons and the mean draught is only 27 feet 6 inches.

These ships will cost about 9 cents per pound of material employed.

The type is evidently highly approved of in Italy, notwithstanding numerous adverse criticisms by the foreign press, and two more similar ships have recently been laid down, the Sicilia and Ré Umberto.

THE SICILIA.

(Plate I.)

The principal dimensions of this vessel are as follows: Length, between perpendiculars, 400 feet; extreme breadth, 74 feet 9 inches; greatest draught, 28 feet 7 inches, and displacement 13,251 tons.

Her four 106-ton guns will be mounted in two separate barbette towers on the midship line, their axes 27 feet 10 inches above load-water line.

Her keel was laid in January, 1886; her unprecedented collective I. H. P. is estimated at 19,500, and her maximum speed at 18 knots.

Her armored deck will be 3½ inches thick, and some improvements in her coffer-dam at the water-line are anticipated.

Before the designs of these ships, the Sicilia and Re Umberto, were finally decided upon, a series of experiments were conducted at Spezia to test the strength of their proposed bottoms.

A caisson was moored in the harbor. It represented a section of the proposed treble bottoms, was covered with an armored deck, and was suitably trimmed and sunk to the required depth. A torpedo containing a charge of 75 pounds of gun-cotton was exploded against it with the result that the outer and inner skins were broken but the interior skin resisted admirably.

The same thing was then tried with one cell filled with coal, and the result was that the outer skin only was broken.*

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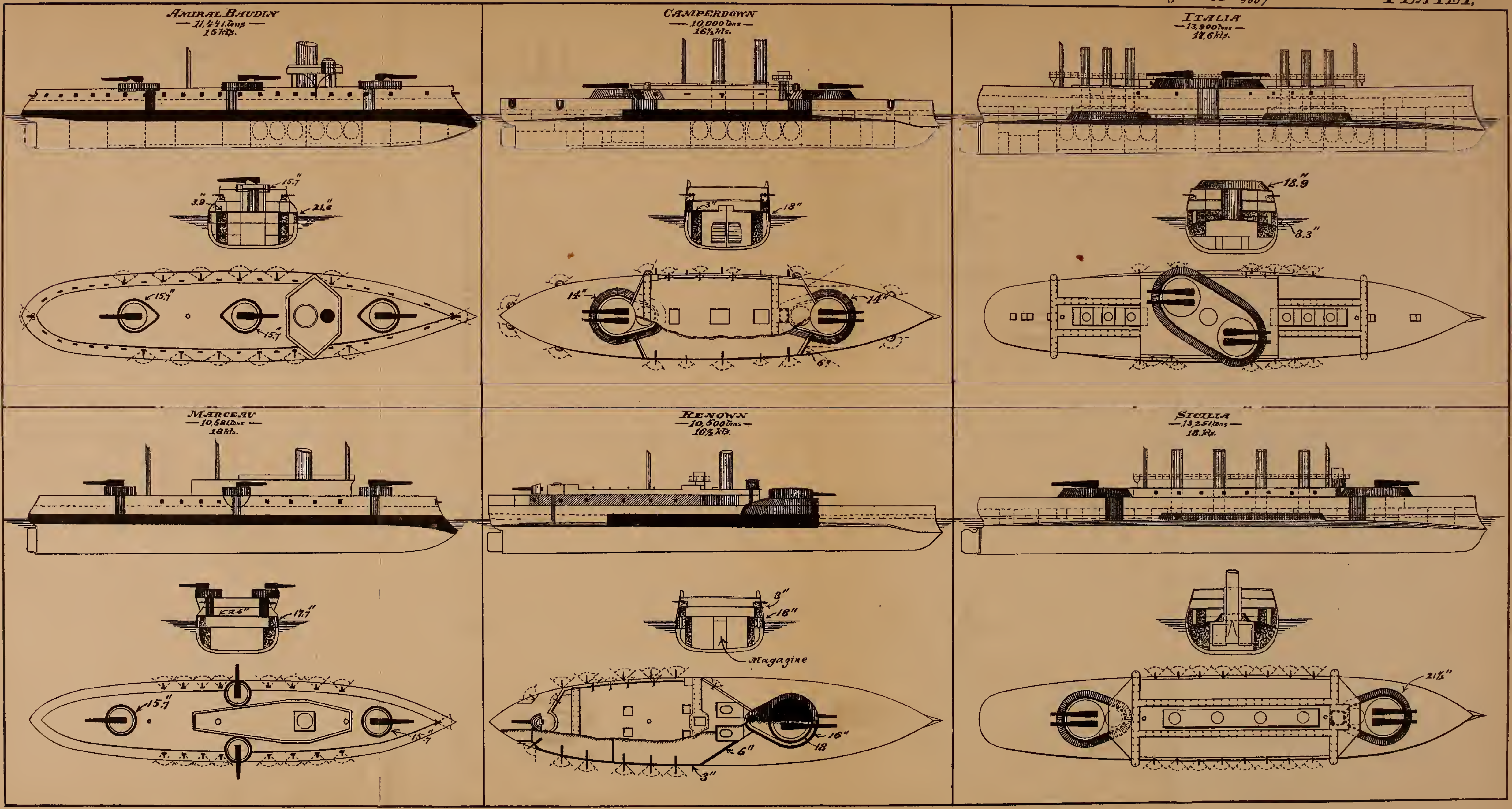
* The Italian Government is fully alive to the importance of fostering and developing home industries; strenuous efforts are being made to render Italy entirely independent of foreign aid in ship-building, and the Italians are fast drawing the attentio of outside purchasers to the superior quality and excellence of the products of thei workmanship.

By way of parenthesis I wish to call attention to the very interesting articles o

(Scale 1/960) PLATE I.



AMIRAL BAUDIN
— 11,441 tons —
15 kts.

CAMPERDOWN
— 10,000 tons —
16½ kts.

ITALIA
— 13,900 tons —
17.6 kts.

MARCEAU
— 10,581 tons —
16 kts.

RENOWN
— 10,500 tons —
16½ kts.

SICILIA
— 13,251 tons —
18 kts.

A temporary departure from the so-called "hybrid," or central citadel, type for the English navy seems to have been made when the sister ships Conqueror and Hero were laid down.

THE CONQUEROR.

(Plate II.)

This ship was laid down in 1879 and launched in 1881.

Principal dimensions.—Length between perpendiculars, 270 feet; extreme breadth, 58 feet; draught, forward, 22 feet; aft, 24 feet; displacement, 6,200 tons.

The hull is of steel, the double bottom extends under engines, boilers, and magazines; nine complete transverse, a central longitudinal, and several minor bulkheads divide the hold into numerous water-tight compartments.

The armor (compound) on the belt is from 7 to 12 inches thick, on the citadel 11 inches, on the conning tower 9 inches, on the turret 12 inches, on the deck above the belt and citadel, and on the short under-water deck at the stern it is from 1¾ to 2½ inches thick. The belt is 7 feet wide and rises 1½ feet above load water-line; the top of the citadel rises 8 feet higher, and the armor is backed by 9 to 15 inches of teak.

The armament consists of two 12-inch 43-ton B. L. R. in the covered. turret, and four 6-inch 4-ton B. L. R. in broadside on the open deck of the superstructure. The secondary battery includes six 6-pounder R. F. and seven 1-inch Nordenfeldt machine-guns, and the torpedo battery, six launching tubes in broadside, four of them being below water.

The engines are compound, vertical, inverted, actuating twin screws and

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this subject which appeared in the Engineer of March 26, 1886, and April 2, 1886, of which the following are brief extracts:

"The rise of iron ship-building in Italy is almost a romance. It owes its origin to the farseeing efforts of Italy's greatest statesman, Cavour."

"Ten years ago it would have seemed ludicrous to the builders on the Clyde had they been told that a country which had no coal worth speaking of, and where iron, though abundant, was difficult to get at, and where, moreover, not half a dozen men knew how to do the simplest iron ship-building job, would, in the course of those years, not only beat them in quality but in price, and would be turning out the largest, the most powerful, and the best built vessels in the world. Such, however, is the case."

"In a short space of time Italy will be able to build as many iron-clads as they and the rest of Europe are likely to require."

"An important bill passed by the Italian Parliament just before the Christmas recess, gives bounties to ship-building and navigation for a period of ten years. The chief features of this bill are (1) a bounty of 24*s*. per ton for iron and steel ships built and registered in Italy; (2) a bounty of 8*s*. per I. H. P. on machinery, and of 2*s*. 5*d*. per cwt. on boilers; (3) a bounty of 10*d*. per ton weight of coal brought to Italy on Italian ships, from ports lying outside the Straits of Gibraltar, provided the cargo is not less than three-fifths of the ship's burden; (4) a bounty on the navigation of 6½*d*. per net ton for every 1,000 miles run from Italy to non-European ports lying beyond the Suez Canal and Straits of Gibraltar. Further, the Italian coasting trade is reserved to the national flag, but foreign ships may be admitted on condition of reciprocity."

situated in two separate compartments. I. H. P. under forced draught 5,859, and under natural draught 4,500. Maximum speed 15½ knots.

There are eight oval, three-furnace boilers situated in four separate compartments. The total coal capacity is 650 tons or 500 tons at normal draught. The complement is 250 officers and men. Weight of hull 4,200 tons, including armored decks; weight of armor and backing 1,720 tons.

In an essay recently published in London entitled "Our war ships," Sir William Cusack-Smith Bart. pays the following compliment to the Conqueror and Hero:

> These ships will be found when the day comes, to do more real fighting work, in relation to their size and cost, than any in our service; and they will not "turn tail" on any adversary at present afloat. however powerful.

It will be noticed that they are of moderate displacement, and that their powers of offense and defense are quite evenly balanced.

The French have also a contemporary type of moderate displacement—the Indomptable class—and a comparison of their relative fighting effiencies would doubtless be instructive, since both may be regarded as completely belted.

THE INDOMPTABLE.

(Plate II.)

This vessel was laid down in 1877, after the designs of M. Sabatier, and launched in 1883.

Principal dimensions.—Length, between perpendiculars, 271 feet 7 inches; length at load water-line, 278 feet; extreme breadth, 59 feet; draft, forward, 23 feet; aft, 24 feet 6 inches; displacement, 7,184.

The hull is constructed of steel with double bottom under engines, boilers, and magazines; nine complete transverse bulkheads and several partial longitudinal ones divide the hold into numerous water-tight compartments.

The armor is compound, 19.7 to 11.8 inches thick on the belt, 16.7 inches thick on the barbettes, and 3¼ inches thick on the armored deck. The vertical armor is backed by from 21.7 to 15.2 inches of wood. The armament consists of two 16½-inch, 75-ton B. L. R. (the projectile of which weighs 1,540 pounds), mounted in the two barbettes, and four 4-inch B. L. R., in broadside on the uncovered superstructure deck. The secondary battery is composed of several Hotchkiss R. F., and 37 millimeter machine-guns, and several torpedo tubes are provided for.

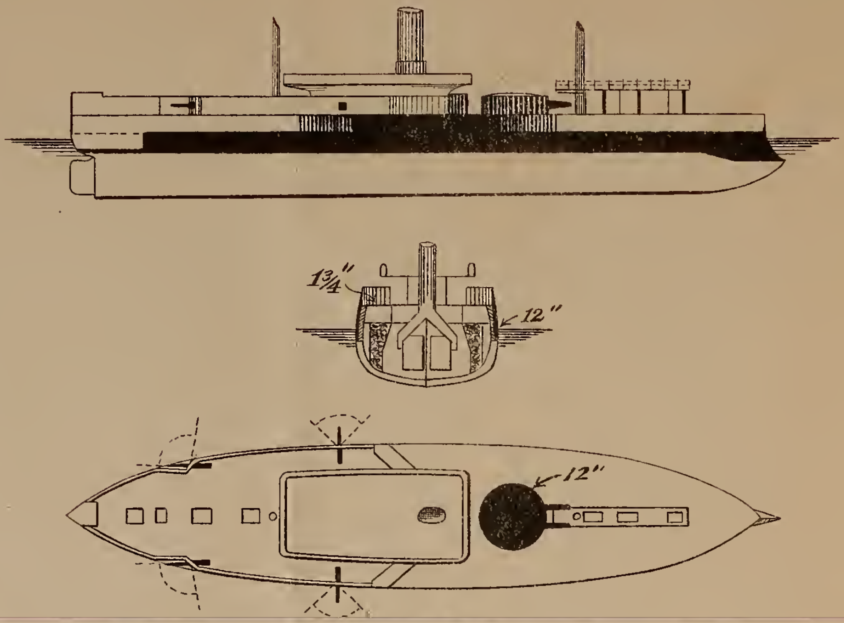
The engines are three cylinder vertical, inverted, compound, in two separate compartments actuating twin screws. Estimated I. H. P. 6,000, and estimated speed 14½ knots. There are twelve two-furnace boilers in four separate compartments with coal-bunkers at the sides.

There are two military tripod masts, in the tops of which a powerful machine-gun battery will be mounted.

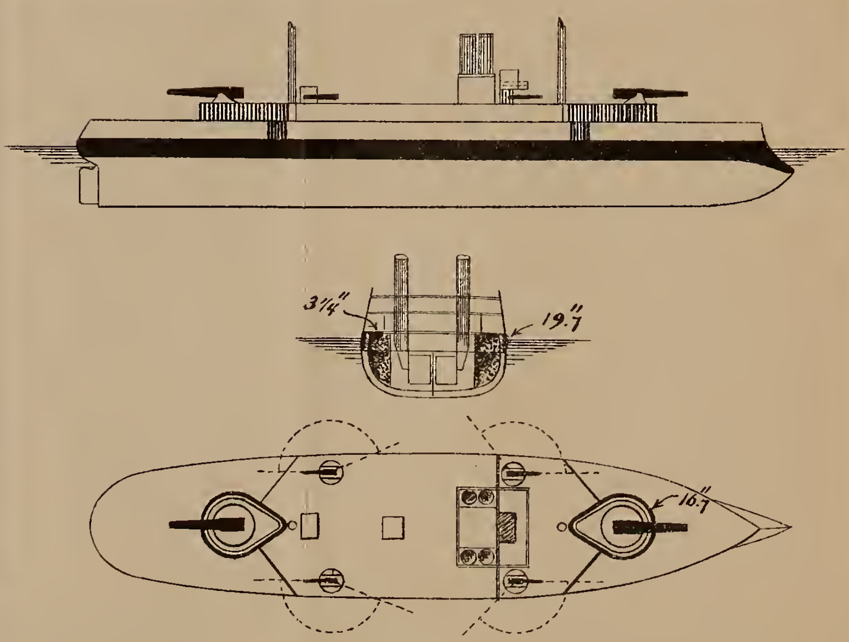
(Scale $\frac{1}{960}$)

PLATE II

CONQUEROR
— 6200 tons —
15½ kts.



INDOMPTABLE
— 7,184 tons —
14½ kts.



The weight of armor carried is 1,744 tons, weight of machinery 1,200 tons, and weight of armament 450 tons.

The sister ships of this type are the Terrible, launched in 1881, the Requin, launched in 1885, and the Caiman, launched in 1885, the latter being of 7,239 tons, with steel armor of 13.8 inches minimum thickness.

Another prominent departure from the central citadel type, evidently an outcome of the agitation inaugurated by Sir E. J. Reed, has recently been made in the laying down of the sister ships Nile and Trafalgar in England.

THE NILE.

(Plate V.)

Principal dimensions.—Length (between perpendiculars), 345 feet; extreme breadth, 73 feet; displacement, 11,940 tons.

This ship will have a water-line belt of armor extending for 230 feet of the length, and an armored citadel 193 feet long on the midship line; both belt and citadel will be covered by a 3-inch steel deck which will bend down at the ends to strengthen the ram and to protect the steering gear.

The armor at the water-line in its thickest parts will be 20 inches; on the citadel, from 16 to 18 inches; and on the turrets, 18 inches. There will also be an inner skin about 2 inches thick, to support the teak backing.

The armament will consist of two 13½-inch 68-ton B. L. R., one in each turret, and eight 5-inch B. L. R. in broadside on a covered deck protected by 3-inch vertical armor. Above this battery, on the spar-deck, there will be a secondary battery of eight 6-pounder R. F., ten 3-pounder Maxim automatic machine guns, and four Gardners.

The engines will be of the vertical, inverted, triple expansion type, situated in two separate compartments actuating twin screws, and developing a collective I. H. P., under forced draft, of 12,000. The estimated speed is 16½ knots. There will be six four-furnace, single-ended boilers. Other details as follows: Diameter of engine cylinders, 43, 62, and 96 inches; stroke, 51 inches; steam pressure, 135 pounds per square inch; grate surface, 604 square feet, or 20 I. H. P. per square foot of grate; weight of machinery not more than 1,050 tons, or 11½ I. H. P. per ton weight of machinery.

The designs of these ships have been severely criticised in the English press for their want of battery power, and it is by no means certain that the type will be extensively reproduced, if we are to judge by the following statement recently made by the Parliamentary Secretary of the Admiralty on presenting the navy estimates before the House of Commons:

> I may safely say that these two large ironclads will probably be the last ironclads of this type that will ever be built in this or any other country.

PART II.—CRUISERS.

In studying the history of ship design in respect of cruisers we find that the Alabama led to our Wampanoag class, which in time called out the English Shah, Inconstant, Raleigh, Rover, Active, Volage, Bacchante, and Euryalus; the French Duquesne, Tourville, and Dugay-Trouin; the Italian Cristoforo Colombo and Flavio Gioja; the German Freya, the Austrian Raditzky and Laudon, and the Dutch Atjeh, all denominated unarmored cruisers.

But before the last examples of this class were far advanced, competing designs appeared for vessels of moderate size, good speed, and powerful armaments, in which the vitals were protected against shell fire.

In 1873 the Russians launched the General Admiral, an armored cruiser of 4,600 tons, with a belt of 6-inch armor, an armored deck, a speed of 14 knots, and good sail power, and the type has recently been reproduced, with slight modifications, in the Vladimir Monomach and Dimitri Domskoi, of about 6,000 tons each, and 15½ to 16 knots speed.

The English Shannon, Northampton, and Nelson, and the French Duguesclin, Turenne, and Vauban are examples of partially-armored cruisers, although it has been customary to class them as ironclads for distant foreign service. Among the latest examples are the English Warspite and Imperieuse, the general features of which are well known. There are, however, certain details of these interesting sister ships which will be new to many of those for whom these pages are written.

THE IMPERIEUSE.

(Plate III.)

This ship was laid down in 1881 and launched in 1883.

Principal dimensions.—Length (between perpendiculars), 315 feet; extreme breadth, 62 feet; draught, forward, 24 feet 6 inches, aft, 25 feet 6 inches; displacement, 7,390 tons.

She is built of steel throughout and with compound armor, the bottom being sheathed with 5½ inches of teak covered with copper. Her double bottom extends throughout the space occupied by engines, boilers, and magazines, and is carried up to the armor shelf. The hold is divided by seven transverse and several partial longitudinal bulkheads into numerous water-tight compartments. The end spaces between the protective platforms and the flats above are minutely divided into water-tight compartments by chain-lockers, store-rooms, and coal-bunkers, and the space between the armored deck and main deck is also subdivided by coal-bunkers.

Her armament consists of four 9-inch 22-ton B. L. R. in the barbettes, six 6-inch 4-ton B. L. R. in broadside, and her secondary battery includes twelve 6-pounder R. F., ten 1-inch Nordenfeldt, and four Gardner machine guns. She is also provided with six torpedo-tubes, four above and two below water.

Her armor is 10 inches thick on the sides, the citadel being 140 feet long, 9 inches on the bulkheads, 8 inches on the barbettes, 3 inches on the ammunition hoists, 8 inches on the conning tower, 2 inches of steel on the armored deck, and 3 inches of steel on the protective platforms. All openings leading through the armored decks are protected by 3-inch glacis plates and coffer-dam casings.

The engines are of the three cylinder (diameters, 55 and 77 inches), vertical, inverted, compound type (stroke, 48 inches), situated in two separate compartments, actuating twin screws.

The crank-shafts are made in three pieces, which are interchangeable, the cranks being placed at an angle of 120 degrees.

The surface condensers, one to each set of engines, together with air-pumps and hot-wells, are of gun metal and so made as to admit of working as common jet condensers if required. Each condenser contains 5,434 brass tubes, with a cooling surface of 8,000 square feet. The cold water is circulated by centrifugal pumps, of which there is one to each main engine, driven by independent engines, the diameter of the fans being 3 feet 9 inches, that of the cylinders 6¾ inches, with a stroke of 15 inches. These pumps are also arranged to pump the ship out in case of accident, with a discharging capacity of 1,000 tons of water per hour, and provision has been made for a direct suction of this water, instead of its having to pass through the condenser.

Each set of engines has two air-pumps, 30 inches in diameter, which are worked by wrought-iron beams by means of links from the cylinder cross-heads, and there are two feed and two bilge pumps to each pair of engines, also worked by these beams.

The screws are each four-bladed, 18 feet diameter, mean pitch 22 feet, the blades being separate and adjustable between 20 and 24 feet pitch.

There are twelve boilers in four separate water-tight compartments, two compartments forward of and two abaft the engine-rooms. Each forward compartment contains two oval boilers with return tubes over the furnaces, and each after compartment four cylindrical boilers with tubes beyond the furnaces, the after boilers being raised so as to allow the shaft-alleys to pass under them. Total grate surface, 676 square feet; heating surface, 22,800 square feet.

For working under forced draft there are four fans 4½ feet diameter for the forward boilers, and four for the after boilers of 5 feet diameter. All openings into boiler compartments are fitted with air-tight doors, provided with air-locks of such size that two men can pass at the same time.

In addition to the auxiliary engines there are four fan engines, having fans 4 feet 6 inches diameter, for ventilating the magazines and other parts of the ship below the armored deck, two powerful horizontal fire engines, six double-cylinder feed engines, two double-cylinder bilge engines, two turning engines, six ash hoisters, one Forrester steering engine, one Harfield capstan engine, one Brotherhood air-compressing engine, three engines for working the electric light dynamos, and a small engine for driving the machinery in the engineer's workshop.

There are also four Friedman's patent ejectors for clearing the bunkers of water in event of their being flooded.

All of the auxiliary engines exhaust their steam into a separate auxiliary condenser placed in the port engine-room, the water from the condensed steam being conveyed into large drain tanks placed under the forward boilers, whence it can be pumped into the feed tanks. The drains from all the steam and exhaust pipes as well as from the whole of the auxiliary engines throughout the vessel are taken into these drain tanks. All main and auxiliary steam pipes are provided with automatic steam traps for keeping the pipes clear of water.

Means have been provided for allowing the steam from the boilers to pass direct into the main surface condensers, when the ship is suddenly stopped, so as to prevent the rush and noise of steam passing through either of the waste steam pipes on deck.

Her trial took place October 14, 1885, 700 tons of water having been admitted into the double bottom to bring her down to the load draught.

The means of the entire run were as follows; steam in boilers, 86.5 pounds; mean collective I. H. P., 10,268:

	Starboard engine.	Port engine.
Revolutions	86.85	87.67
Vacuum	27.25	28.00
Mean pressures:		
High	44.48	44.60
Low	13.86	14.04

The total consumption of fuel per unit of I. H. P. did not exceed 2½ pounds. Mean speed 17.213 knots.

Very little appreciable vibration was observed, and it is thought the sheathing on the bottom absorbed much of the commotion usually produced by screws.

On trial of the steering gear it was found that it required only fifteen seconds to get the tiller hard over (35°), the estimated pull on the chain being 17 tons. The half circles to starboard and port were accomplished in two minutes fourteen seconds, and the full circles in four minutes thirty-one seconds, the mean tactical diameter being 1,800 feet.

The ship can also be steered by manual appliances from two positions, eight turns being necessary to get the helm over by hand and four by the engine.

On October 16, 1885, her low-speed trials gave:

	Revolutions.	I. H. P.
At 8 knots	35	825
At 9 knots	43	1,343
At 10 knots	48	1,581

The steam in the latter case being 60 pounds and vacuum 29.25. In all these trials the engines were worked at the highest grade of expansion, four boilers being cut off. The coal consumption at 10 knots was 1.92 pounds per I. H. P. Her coal capacity is 1,200 tons. Endurance at 10 knots, 37.3 days or 8,950 miles. Endurance at maximum speed, 4.4 days or 1,800 miles. She is brig rigged and will carry a complement of 490 officers and men.

In the remarks on battle ships (Part I) reference was made to the minority report of the "committee on designs," of 1871, made by Admirals Elliot and Ryder, who strongly advocated the use of a "protective deck," in conjunction with other features, instead of side armor for protection to stability.

The idea, as regards cruisers, was first carried out in the full-rigged ships of the English Comus class, of 2,380 tons displacement and 13 knots speed, launched in 1878, in which the engines, boilers, and magazines are covered by a horizontal 1½-inch steel deck placed below the water line, the space immediately above containing cellular subdivision.

Then followed, in 1882, the Leander and her three sisters, bark-rigged vessels, which are a compromise between the speed of the Iris and the protection of the Comus. They are of 3,750 tons displacement and 17 knots maximum speed; they carry ten 6-inch 4-ton B. L. R., and 725 tons of coal, and have a "partial protective deck," covering engines, boilers, and magazines, which is 1½ inches thick, and which bends down below the load water-line at the sides.

Our new cruisers, the Chicago, Boston, and Atlanta, bear a closer resemblance to this type than they do to any other in respect of their protection.

About this time the Chilian cruiser Esmeralda, of 3,000 tons, appeared, having a protective deck complete, from stem to stern-post, carrying an exceptionally heavy battery and coal supply, and withal attaining the unprecedented speed of 18.28 knots.

Italy was not slow to perceive the advantages of this type, and accordingly bought an improved Esmeralda, the Giovanni Bausan, of her builders, and at once commenced to build five others, the Vesuvio, Stromboli, Etna, and Fieramosca, of 3,530 tons each.

Japan also ordered two improved Esmeraldas, the sister ships Naniwa-Kan and Tacachiho-Kan, from Armstrong, in England, and a similar vessel, the Unebi, in France.

England also laid down a similar class, the Mersey, and three others, and France a similar cruiser, the Sfax, of 4,400 tons.

THE NANIWA-KAN.

(Plate III.)

This vessel was laid down in 1884 and completed in 1885 by Sir W. G. Armstrong & Co., Elswick Works.

Principal dimensions.—Length between perpendiculars, 300 feet;

moulded breadth, 46 feet: draught, forward, 17 feet 6 inches; aft, 19 feet 6 inches; displacement, 3,730 tons.

The hull is constructed of steel throughout, with double bottom under engines and boilers, and a steel protective deck, 2 to 3 inches thick, complete from the ram to the stern-post, its edges 4 feet below, and its crown 1 foot above the load-water-line. Ten complete transverse and several partial bulkheads divide the hold into many water-tight compartments. The space between the protective deck and the main deck is very minutely subdivided into water-tight compartments occupied as coal-bunkers, store-rooms, chain-lockers, and torpedo-rooms. The conning-tower is protected by 2 inches of steel armor, and two ammunition hoists, 3 inches thick, lead direct from the shell-rooms to the loading-towers at the breech of each of the 10-inch guns. The freeboard is 15 feet and the axes of the broadside guns are 18.2 feet above the load-water-line.

The armament consists of two 10-inch 28-ton B. L. R. central pivots, the hydraulic revolving and loading gear and the recoil cylinders being protected by 2-inch steel screens, and six 6-inch 4-ton B. L. R. on central pivot carriages and spar-deck sponsons in broadside. The secondary battery includes two 6-pounder R. F., eight 1-inch Nordenfeldt, and four Gardner machine guns.

The torpedo battery consists of four launching tubes mounted above water in broadside.

The hydraulic power which actuates the gun mechanism is the same as that which operates the steering-gear, and the 10-inch guns can be fired at point blank in a fore and aft direction without damage to the deck below.

The engines are of the horizontal (or slightly inclined) compound type, situated in two separate compartments, one abaft the other, actuating three-bladed twin screws. I. H. P. under forced draught 7,650; maximum trial speed, 18.9 knots, the mean of two runs over a 10-mile course at load draught.

There are six single-ended locomotive three-furnace boilers in two separate compartments with athwartship fire-rooms.

This ship has two military masts, no sail power except storm sails; her normal coal capacity is 450 tons, but 800 tons can be carried, which increases her draught 1 foot 6 inches; her endurance at 10 knots is about 8,600 miles and at 8 knots about 11,000 miles, and her complement is 325 officers and men.

THE MERSEY.

(Plate III.)

This vessel is very similar to the Naniwa, and I shall simply note the main points of difference between the two. She has compound engines, although it is probable that her sisters, the Severn, the Thames, and the Forth, will be fitted with the triple expansion type.

With the same length and breadth as the Naniwa, her draught is, forward, 16 feet; aft, 20 feet; and displacement, 3,550 tons.

Her main battery consists of two 8-inch 13-ton B. L. R. on central pivots, forward and aft, and ten 6-inch 4-ton B. L. R. in broadside on covered deck; her secondary battery contains ten 1-inch Nordenfeldt and two Gardner machine guns; and her torpedo battery consists of six Whitehead tubes in broadside above water.

Her conning-tower is protected by 9 inches of compound armor.

Her ram is strengthened in a novel way by a horizontal steel stiffener 3 inches thick, which penetrates the snout and projects outside the skin on either side.

Her double bottom extends under the magazines beyond the machinery and boiler spaces. Her main deck battery is 12 feet above the load-water line; total coal supply 750 tons, and maximum speed estimated at 17½ knots.

The development of the Mersey design has resulted in the new English "belted cruisers," in which to satisfy the demand for a water line belt of armor (previously cited in Part I) the displacement has been increased to 5,000 tons. Seven of this class recently laid down are in process of construction by private firms, and they are to be ready for delivery within two and a half years.

They are to be named Orlando, Narcissus, Australia, Galatea, Aurora, Undaunted, and Immortalité.

THE ORLANDO.

(Plate III.)

Principal dimensions.—Length between perpendiculars, 300 feet; extreme breadth, 56 feet; draught, forward, 19 feet 6 inches; aft, 22 feet 6 inches; displacement 5,000 tons.

The hull will be of steel throughout, the double bottom extending under engines, boilers, and magazines. Eleven complete transverse and several partial bulkheads will divide the hold into numerous water-tight compartments, and the space between the armored deck and the main deck will be minutely subdivided and occupied by coals, cables, stores, and torpedo-rooms, the steel bulkheads being kept as light as possible.

The belt will cover about 195 feet in length of the side, extending from 1½ feet above to 4 feet below the load-water line, and will be of compound armor 10 inches thick, backed by 6 inches of teak. The armored deck will be from 2 to 3 inches thick, the conning-tower 13 inches, and the ammunition-hoists 3 inches.

The armament will consist of two 9-inch 18-ton B. L. R. at bow and stern, unprotected except by machine-gun-proof shields, and ten 6-inch 4-ton B. L. R. in broadside on spar deck, mounted on central pivot carriages.

The secondary battery will include six 6-pounder R. F. and ten 1-inch Nordenfeldt machine guns; and the torpedo battery eight launching tubes in broadside, four above and four below water.

The engines will be of the horizontal triple expansion type, situated in two separate compartments and actuating twin screws. Estimated I. H. P. 8,500, and speed 17½ to 18 knots. There will be four double-ended three-furnace boilers and four separate water-tight fire-rooms. Grate surface 540 square feet, or 15¾ I. H. P. per square foot of grate. Total weight of machinery less than 800 tons, or 10½ I. H. P. per ton weight of machinery. Working pressure of steam 130 pounds.

These ships will have two military masts, no sail power other than storm sails, will carry 350 officers and men, and a normal coal supply of 900 tons.

In respect of their mechanical and other appliances, such as duplicate steering gear, mechanical ventilation, pumping and draining arrangements, ammunition lifts, telegraphs, indicators, tell-tales, voice-tubes, &c., these vessels will be as perfect as modern engineering science and constructive skill can make them.

In improving upon their cruiser, the Sfax, the French have recently laid down, at a private yard, the Cécile, which, with the exception of her rig and the disposition of battery, embodies the general features of the Esmeralda type.

THE CÉCILE.

Principal dimensions.—Length between perpendiculars, 379 feet; extreme breadth, 49 feet; depth of hold, 35 feet; mean draught, fully equipped, 20 feet; deep displacement, 5,766 tons.

The hold is divided by fifteen complete transverse water-tight bulkheads extending up to the protective deck, which is complete from stem to stern-post. A horizontal screen for shell splinters extends over the boilers, engines, and magazines below the protective deck. The cellular space above the protective deck will be filled with coal, stores, &c., around the whole of which extends a complete coffer-dam belt of cellulose.*

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* Some years ago a plan was devised for protecting the masonry quays of the Seychelles Island from the damaging effects of waves, by erecting a palisade of bamboo canes and filling in the spaces between it and the masonry with the fiber forming the husk of the cocoa nut. This coffer-dam was found to behave like a sponge and to offer a most efficient shield.

The great success of this expedient led to certain recent experiments at Toulon, with the following results:

A target was composed of fourteen parts of cellulose and one part of cellulose in fiber, the whole compressed into a felt-like mass, with a lining 2 feet thick. A shot of 7½ inches caliber was fired against this strange target at a distance to insure penetration. The result was not only satisfactory, but most extraordinary. The shot, which carried away about one-fifth of a cubic foot of the composition, had no sooner passed through than the cellulose closed up so firmly that a strong man was unable to insert his arm into the hole. A tank filled with water was then hung against the

The armament will consist of six 6¼-inch (16 centimeter) B. L. R., on the spar-deck, one forward, one aft, and four on sponsons; ten 5½-inch (14 centimeter) B. L. R., in broadside on covered deck; ten (37 millimeter) Hotchkiss guns, and four torpedo-tubes.

There will be (1) two main engines, each actuating a screw, in two separate compartments, estimated I. H. P., at natural draft, 6,900, at forced draft, 9,600; (2) eight donkey engines for driving the air, feed, and bilge pumps; (3) a small engine for turning the main engines when cold; (4) eight small engines for driving ventilating and forced-draft fans.

Maximum speed estimated at 18½ knots.

There will be six boilers in three separate compartments, each boiler being so arranged as to permit of being entered while the others are under pressure. There will also be three auxiliary boilers.

The draining of this vessel will be effected by means of a collecting drain, placed near the keel, with which the suction pipes of two powerful pumps will be connected, whereby it will be possible to free the ship of 1,000 tons of water per hour. All the water from the holds, rooms, &c., will be diverted into this drain. Hand-pumps will be provided, and, in addition, a 90-ton pump will be supplied for emptying the ballast-tanks.

She will be lighted by electricity throughout, and will be provided with powerful search-lights with Mangin projectors.

She will be ship-rigged, with a sail area of 2,153 square yards. Her lower masts will be of steel, each surmounted by a military top, and they will serve as ventilators for the hold.

To be completed in 1888.

When improvements in offensive power, protection, or speed are introduced in modifying contemporary designs, the result is usually an increase in displacement, as is exemplified in the design of the most recent French cruiser.

THE TAGE.

(Plate III.)

This vessel is in most respects an exact copy of the Cecile.

Principal dimensions.—Length between perpendiculars, 390 feet; extreme breadth, 53 feet 8 inches; depth of hold, 36 feet; mean draught, 22 feet 10 inches; difference of draught, 3 feet 7 inches; displacement, 7,045 tons.

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place where the shot had entered, and after an interval of fifteen minutes water began to trickle through, but not more than a man with a pail could easily intercept. As soon as the composition became thoroughly soaked it offered increased resistance to the entrance of water, which eventually ceased to flow, and the breach was closed automatically.

The results were the same when shells were used instead of shot, and red-hot coals were heaped upon the cellulose without causing its ignition.

Her protective deck will be somewhat stronger, and better protection will be afforded the hatchways and conning-tower. I. H. P., under natural draft, 8,115, and under forced draft, 10,330. Estimated speed, 19 knots.

Her main battery will be the same as that of the Cecile, but her secondary battery will be more powerful, and she will carry seven torpedo-tubes above water.

Weight of hull, 2,487 tons; weight of engines, filled boilers, and auxiliary engines, 1,764 tons, and weight of artillery, without equipment, 272 tons.

The praises of the Brazilian armored ship Riachnelo have been widely sung, and the type seems to have met with much favor in this country.

The Aquidaban, a newer vessel, is almost an exact reproduction of her noted prototype, though on a smaller scale, and she seems to be a compromise between a battle-ship and a cruiser.

For the purposes of illustration it will be convenient to classify her as an armored cruiser, and to compare her with a more recent cruiser of about the same displacement.

THE AQUIDABAN.

(Plate IV.)

This ship was launched in 1885, and consumed only nineteen months in building.

Principal dimensions.—Length, 280 feet; extreme breadth, 52 feet; greatest and mean draught, 18 feet; displacement, 4,950 tons.

The hull is built of Siemens steel with the exception of the stem and stern-post, which are of gun metal, and is sheathed to a height of 2 feet above load-water line, with 6 inches of teak covered by copper.

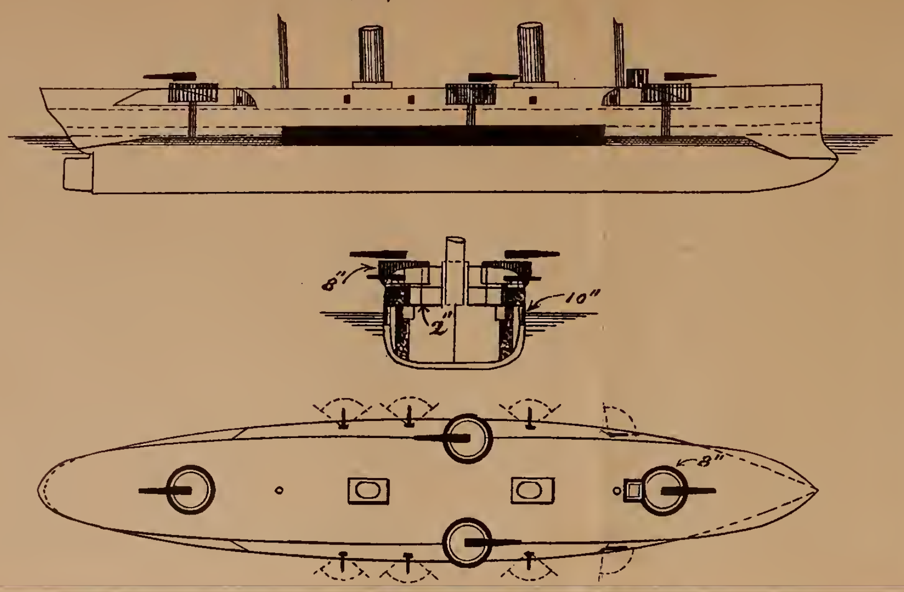
The hold is divided by several partial longitudinal and ten complete transverse bulkheads into numerous water-tight compartments. The armor is compound, 11 to 7 inches on the belt, 10 inches on the conning-tower, the turrets, and the oval redoubts surrounding the bases of the turrets; and the armored deck and the roofs of the redoubts are of steel, 2 to 3 inches thick.

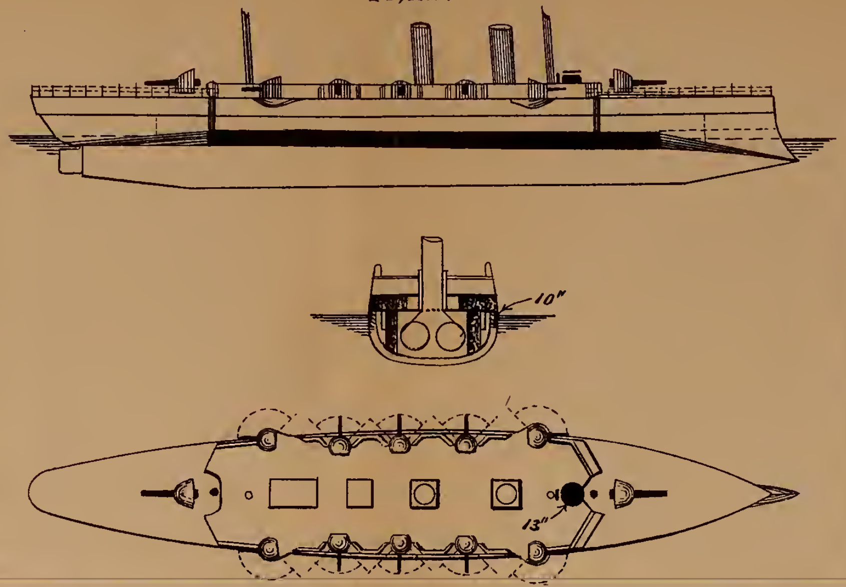
The armament consists of four 9-inch 20-ton B. L. R. in the covered turrets, four 5¾-inch B. L. R., mounted under cover in the superstructure at the ends; a secondary battery of fifteen 1-inch Nordenfeldt machine guns, and a torpedo-battery of five launching-tubes, four in broadside and one astern, all above water.

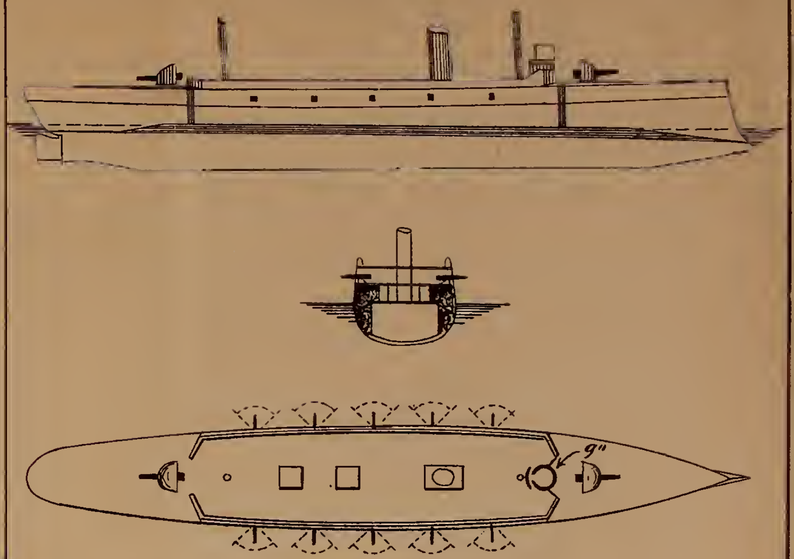
The engines are three-cylinder, compound, vertical, inverted, situated in two separate compartments, actuating two-bladed twin screws. I. H. P., under natural draft, 5,270, for a speed of 15.257 knots, and under forced draft, 6,251, for a speed of 15.818 knots.

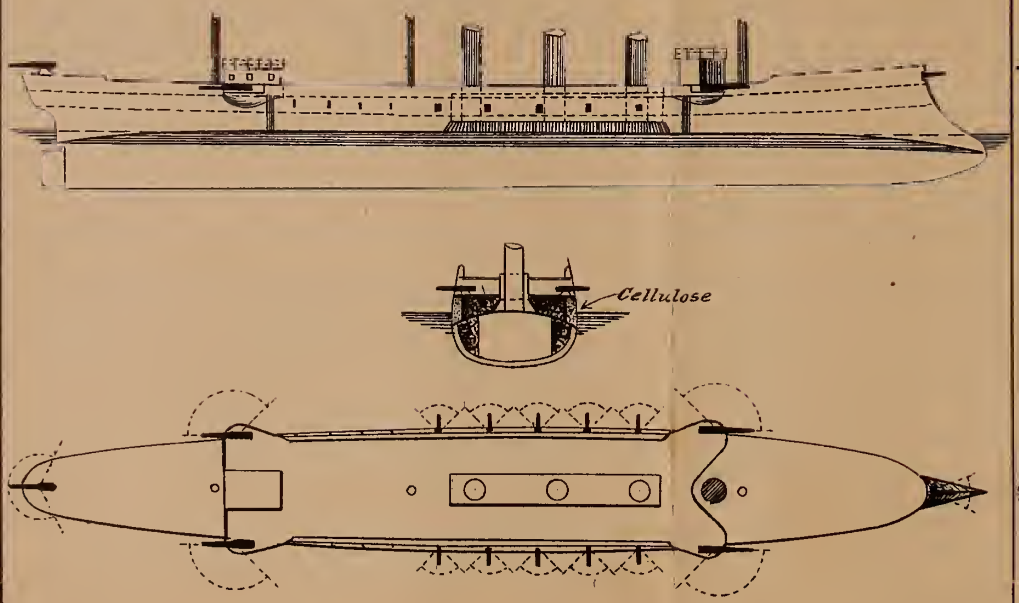
There are eight main and two auxiliary boilers in four separate compartments.

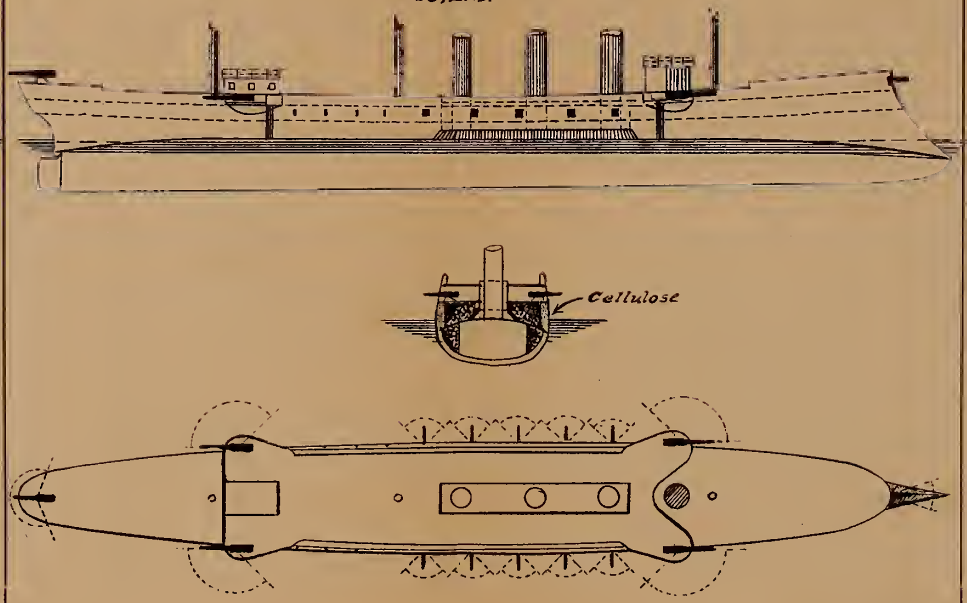
(Scale $\frac{1}{960}$) **PLATE III.**

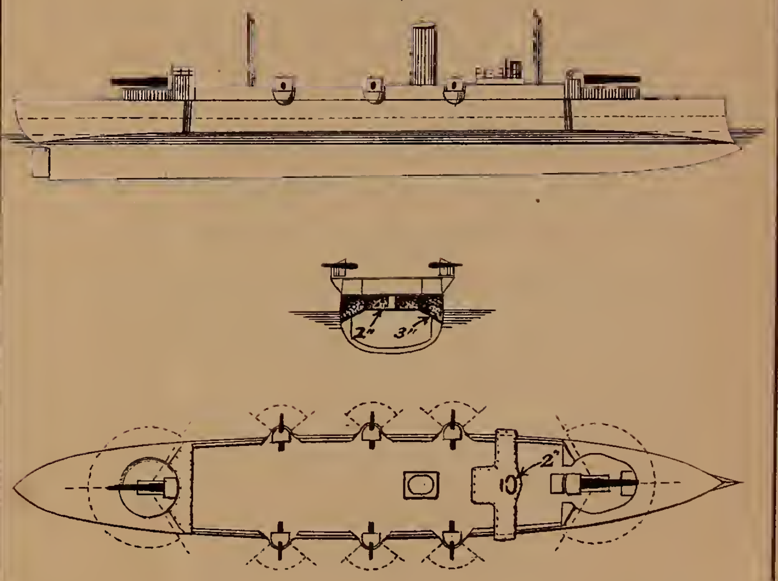












The total coal capacity is 800 tons, and the coal capacity at normal draft, 400 tons. Endurance, 6,300 miles at 10 knots per hour.

She is ship-rigged, and carries 250 officers and men.

Towards the end of last year, after the German occupation of the Caroline Islands, the Spanish authorities issued invitations to fifteen of the most prominent private ship-building firms of England and the continent to tender competing designs for a certain cruiser. Those of Messrs. J. & G. Thompson & Co., of Clydebank, were finally selected.

Certain conditions were laid down, the chief of which were that the ship should have a displacement of not more than 4,300 tons, a speed of at least 19 knots, and a fuel endurance, at cruising speed, of at least 5,000 knots.

THE NEW SPANISH CRUISER.

(Plate IV.)

Principal dimensions.—Length, 300 feet; moulded breadth, 50 feet; moulded depth, 31 feet 6 inches; mean draught, 20 feet; displacement, 4,300 tons.

The hull will be of steel, unsheathed, with cellular double bottom under engines and boilers, the sides, however, being single above the floor, and the hold will be divided by eleven complete transverse bulkheads and several partial ones into many water-tight compartments.

The protective deck will be unusually strong, 4¾ inches on sloping part and 3 inches at crown over engines, boilers, and magazines; before and abaft these spaces it will be 3¾ and 2 inches in thickness.

The space between the main deck and the protective deck will be minutely subdivided into coffer-dams and compartments for coal, stores, and torpedo-rooms.

Her freeboard will be about 14 feet, her quarters will be exceptionally comfortable and well ventilated, her metacentric height will be not less than 2½ feet when fully laden, and her reserve buoyancy will render her practically uncapsizable.

The armament will consist of four 8-inch 13-ton B. L. R., partially sponsoned on each side of poop and forecastle, with their axes about 27 feet above the load-water-line, and six 5-inch Hontoria B. L. R. on sponsons in broadside. The secondary battery will include six 6-pounder R. F, four 1-inch Nordenfeldt, and four 11-millimeter Nordenfeldt machine guns; and the torpedo-battery five tubes, two ahead, two in broadside, and one astern, all above water.

The engines will be of the triple expansion type in two separate compartments. I. H. P. under forced draft, about 11,000.

The guaranteed speed under natural draft is 18½ knots, and under forced draft, 20½ knots.

Total coal capacity about 1,100 tons or about 600 tons at normal draught.

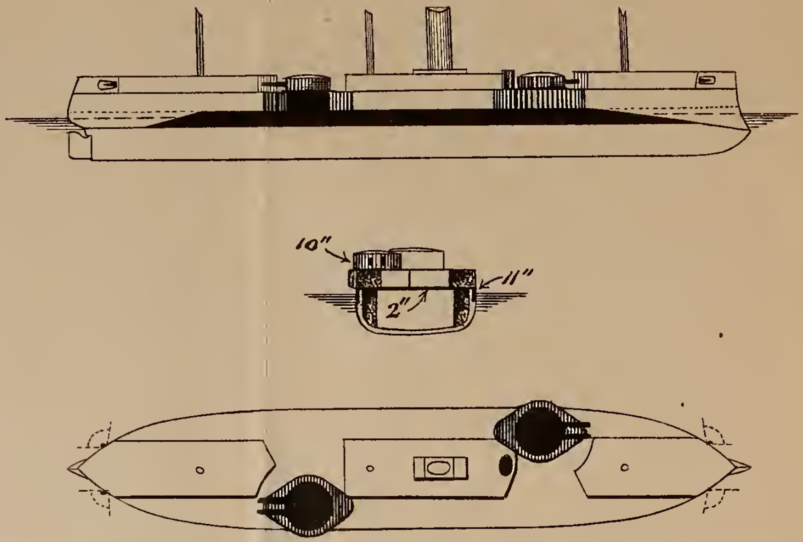
Endurance about 17,000 miles at 8 knots or about 10,400 miles at 10 knots.

Complement, 300 officers and men.

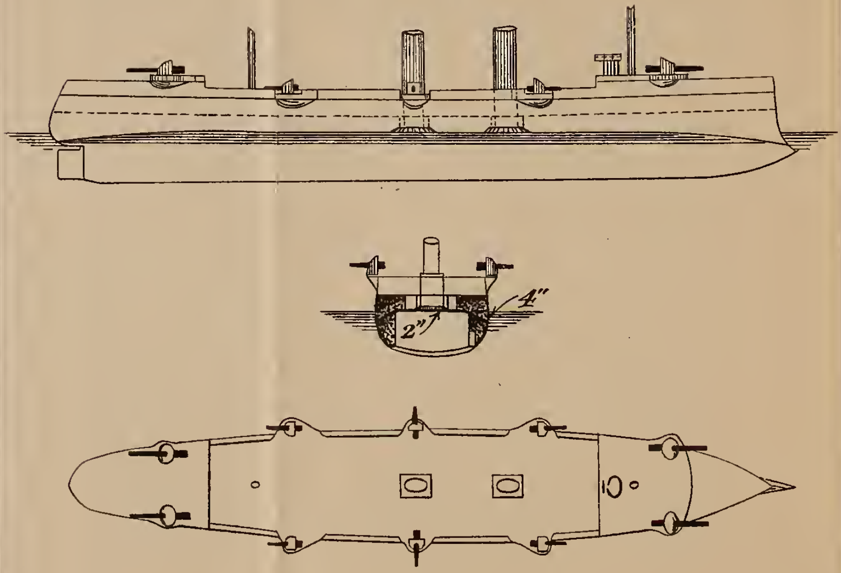
In the foregoing classification it will be noticed that the growth of types has been followed along the line of protection to stability. There are differences, however, in the disposition of battery and the height of freeboard, which give different characters to designs, which in other respects are generally similar. They will be referred to later.

(Scale 1/960) PLATE IV

AQUIDABAN
— 4,950 tons —
15.8 kts.



NEW SPANISH CRUISER
— 4,300 tons —
20½ kts.



PART III.—OTHER VESSELS OF THE CRUISING AND FLEET SERVICE TYPES.

Much attention of late has been devoted to the development of torpedo-vessels of various classes, and there is so much of novelty and interest in the subject that it deserves a special study which is not within the scope of this article.

Our comparison would be incomplete, however, without including a brief reference to some of the latest examples.

Plate V will show at a glance the relative sizes of target and the characteristic features of certain typical vessels in contrast with those of the English battle-ship Nile.

In the French navy there are four of the torpedo cruiser class building, the Condor, Epervier, Faucon, and Vautour.

THE FAUCON.

This vessel, designed by Mr. De Bussy, was laid down in 1883 and launched in 1885.

Principal dimensions.—Length between perpendiculars, 216½ feet; extreme breadth, 29 feet 2 inches; draught, forward, 12½ feet; aft, 15½ feet; displacement, 1,249 tons.

Armament.—Five 4-inch B. L. R., two on projecting breastworks at the sides with arcs of fire of 180 degrees, two in recessed ports under the forecastle, and one on central pivot aft on poop-deck. The secondary battery includes two Hotchkiss R. C. on fixed mountings on each side of the bridge and four H. R. C. so arranged as to be transportable to either side. The torpedo-battery consists of two tubes forward, one on each side of the stem above water, with a train of 20 degrees each, and one fixed tube aft, all above water.

The hull is built of steel, is divided into numerous water-tight compartments, and the protective deck, continuous fore and aft, is 2 inches thick, with a complete belt of cellulose above it.

The engines are horizontal and compound, in one compartment, actuating twin screws. Estimated I. H. P., 3,200 under forced draft. There are four boilers in two separate compartments. Estimated speed, 17 knots.

In the English navy this class is represented by the Scout, Fearless, Archer, Brisk, Cossack, Mohawk, Porpoise, Tartar, and one not named.

THE ARCHER.

(Plate V.)

Principal dimensions.—Length, 225 feet; extreme breadth, 36 feet; draught, forward, 12½ feet; aft, 14½ feet; displacement, 1,630 tons.

Armament.—Six 6-inch B. L. R. on sponsoned pivots, one on each side of forecastle and poop and one on each side of the main deck in the waist. The secondary battery includes eight 1-inch Nordenfeldt machine guns, and the torpedo-battery ten launching tubes, one ahead, one astern, eight in broadside, all above water except two of the broadside tubes.

The hull is built of steel, is greatly subdivided, and the protective deck, which is complete fore and aft, is only three-eighths of an inch thick.

The cellular space, however, above the protective deck and over the engines and boilers is occupied as coal-bunkers.

The engines are horizontal and compound in two separate compartments and actuate twin screws.

The original estimate of speed, was 17 knots for an I. H. P. of 3,500, but on her recent preliminary trial trip she attained a speed of 18 knots on an I. H. P. of 4,250. There are four boilers in two separate compartments.

Endurance at maximum speed, about 2,600 miles; at 10 knots, twenty-nine days or 7,000 miles. Complement, 140 officers and men.

The Austrians possess the swiftest of this class, the Panther and Leopard, both built at the Elswick Works in England.

THE PANTHER.

(Plate V.)

Principal dimensions.—Length, 224 feet; extreme breadth, 34 feet; mean draught, 14 feet; displacement, 1,550 tons.

Armament.—Four long-range Krupp B. L. R., mounted on sponsoned pivots, two on each side, and numerous R. F. and machine guns.

The torpedo-battery consists of four above-water tubes, one at bow, one at stern, and one at each side.

The principal points in which this vessel differs from the Archer and Condor are—(1) the protective deck is not continuous, (2) the engines are of the vertical, inverted, triple-expansion type, and (3) the engine cylinders projecting above the water line are protected by steel shields surrounded by either coal or sand bags.

Speed under natural draft, 17.6 knots; under forced draft, 18.9 knots.

There is a consensus of opinion that the foregoing class of vessels, denominated "torpedo-cruisers," are too important as adjuncts of the fleet to be used as torpedo-boat hunters or "torpedo-catchers." The Archer, for instance, would be large enough for an object of attack, and her destruction would compensate for the loss of one or two torpedo-boats. In a fleet action the Condor's rôle would possibly and very properly be that of "torpedo-ram."

For the protection of a blockading fleet against torpedo-boats a smaller class has been laid down, called by the French "*torpilleurs avisos*," and by the English "torpedo-catchers," "torpedo-hunters," or "torpedo-gunboats," of which the Bombe in France and the Grasshopper in England are good examples.

THE BOMBE.

(Plate V.)

Principal dimensions.—Length, extreme, 196.8 feet; extreme breadth, 21.6 feet; greatest draught, 6 feet; displacement, 321 tons.

Armament.—Two 4-inch B. L. R., mounted on central pivots in breastworks at the sides, with arcs of 180 degrees each, and three Hotchkiss R. C., two forward and one aft. Her torpedo-battery includes two above-water tubes on each side of the stem.

The hull is of steel, subdivided by eight complete transverse and several partial longitudinal bulkheads, and two complete steel decks. A belt of cellulose at the sides and above the lower deck protects the water line.

There are two engines, each in a separate engine-room, actuating twin screws, and in each compartment there is a syphon ejector with a discharging capacity of 40 tons per hour.

Normal coal supply 46 tons, and room for the stowage of more. Speed, 18 knots.

THE LATEST OF THE GRASSHOPPER TYPE.

(Plate V.)

Principal dimensions.—Length, 200 feet; breadth, 20 feet; depth, 13; feet; mean draught, 8 feet; displacement, 450 tons.

Armament.—One 4-inch B. L. R. on central pivot in the bow, three 3-pounder R. F., and other machine guns. The torpedo-battery will include four launching tubes, one forward and one aft, under cover, and two broadside tubes in the open.

The hull will be of steel, the decks covered with wood planking, and the engines and boilers will be protected by a three-quarter-inch steel deck and coal-bunkers 3 feet wide.

The engines will be of the triple-expansion type, driving twin screws, I. H. P. about 2,700, and there will be four locomotive boilers. Speed, 18½ to 19½ knots.

One of the most successful vessels of the class specially designed for hunting or destroying torpedo-boats is that built at a private venture by Mr. White, of Cowes, England, and recently purchased by the Admiralty. (See Plate V.)

Her length is 150 feet and displacement 220 tons. She has two conning towers, and is armed with three 1-inch Nordenfeldt machine guns and four launching tubes.

Her principal novelty is her remarkable maneuvering power, and on her recent trials she developed a speed of almost 21 knots.

The Russians have recently laid down at St. Petersburg a novel vessel, which represents a very efficient class of "torpedo-gunboat," although she may be classed as either torpedo-cruiser or torpedo-destroyer.

THE NEW RUSSIAN TORPEDO-GUNBOAT.

(Plate V.)

Principal dimensions.—Length, 230 feet; breadth, 24 feet; mean draught, 9 feet; displacement, 600 tons.

I. H. P., 3,500. Speed, over 20 knots. Fuel endurance, about 2,000 miles at 12 knots.

Armament.—Eight 47-millimeter Hotchkiss R. C. on light sponsons on the main deck; and sixteen 37-millimeter Hotchkiss R. C. on upper deck and bridge.

Torpedo-battery.—Seven above-water tubes, one on each side of the stem, one at port side of stern-post in the cabin firing aft, and four in broadside.

A light protective deck extends from end to end, being curved in transverse section, and the coal protection above the boilers is entirely reserve fuel.

Another of the numerous special torpedo-vessels is the "torpedo-ram" Polyphemus, which is generally regarded as a costly but successful experiment and which has received much attention of late.

THE POLYPHEMUS.

(Plate V.)

Principal dimensions.—Length (between perpendiculars), 240 feet; extreme breadth, 40 feet; draught forward, 20 feet, aft, 21 feet 3 inches; displacement, 2,640 tons.

Armament.—Six 1-inch 5-barrel Nordenfeldt in towers and several lighter machine guns. Torpedo supply 40, operated from five tubes under water, one ahead, and two on each broadside.

The hold, which is divided into numerous water-tight compartments by ten complete transverse and several partial bulkheads, is protected by a turtle-back protective deck covered with Whitworth steel plates, the crown being 2 inches and the sides 3 inches thick. Light superstructures are built above this deck at the ends, and a flying deck in the middle, with communication through trunks between the flying deck and the hold protected by glacis plates and coffer-dams.

The keel is hollow and contains 300 tons of lead ballast, which may be detached in sections at will for reserve buoyancy.

There are two lifting balance rudders in the bow, one on each side of the bow tube.

The engines are compound and horizontal, actuating twin screws, and situated in two separate compartments, one abaft the other; I. H. P., 5,780.

There are eight boilers in four separate fire-rooms. Total coal capacity, 300 tons, or 200 tons at normal draught. Complement, 132 officers and men. Maximum speed, 17.8 knots.

The arguments in her favor are thus set forth by Commander Galwey (See Proc. Royal United Service Institution, March 6, 1885):

I. That she has a very high speed, combined with fair maneuvering power.

II. That she can discharge her torpedoes with certainty, either ahead or on the beam, when proceeding at full speed.

III. That her crew and weapons of offense are protected by the most perfect armor possible, viz, 10 feet of water.

IV. That she only presents a mark of 4 feet above the water line.

Her want of habitability renders her very uncomfortable at sea, but in the two new torpedo-rams recommended by the English Admiralty the quarters will be situated in ship-shaped and airy superstructures above the turtle-back decks, which will give them sufficient reserve buoyancy to discard the detachable ballast from the hollow keel. If this is done and her armament is increased as proposed, a type of "torpedo-rams" intermediate between the "torpedo-cruisers" of the Scout class and "ram-cruisers" of the Esmeralda class will be developed.

In other words, if the Scout's dimensions were somewhat enlarged, her turtle-back or protective deck increased in thickness, and her battery somewhat reduced, or if the Esmeralda's dimensions and her battery were somewhat reduced, they would both approach the condition of the proposed torpedo-rams of improved Polyphemus type.

In respect of armored coast-defense vessels, more attention has been paid of late to the gunboat class—800 to 1,600 tons—than to the heavier batteries, and France, Germany, and Holland are the countries in which it is favored.

In France there are in process of construction the sister gunboats Fusée, Grenade, Mitraille, and Flamme, of 1,045 tons each, and the Achéron, Cocyte, Phlégeton, and Styx, of similar type, but of 1,639 tons. Germany has eleven of a similar type, of 1,109 tons, and two of 875 tons.

THE FUSÉE.

(Plate V.)

This vessel, the first of her class, was laid down in 1882 and launched in 1884.

Principal dimensions.—Length, 165 feet; beam, 32 feet 7 inches; draught, 10 feet 4 inches; displacement, 1,045 tons.

The hull, of iron and steel, is extensively subdivided by numerous bulkheads into water-tight compartments, and is protected at the water line by a complete belt of steel armor 9.45 to 7.1 inches thick, which rises a few inches only above the load-water-line.

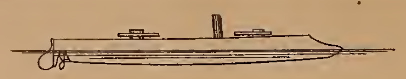
The steel-armored deck is somewhat arched, 2 inches thick, and the steel armor on the barbette tower is 4 inches thick. The superstructure above the armored deck is protected against the ingress of water by a coffer-dam belt of cellulose.

Armament.—One 10.6-inch B. L. R. *en barbette*, one 3.54-inch B. L. R. on a stern pivot, two 3-pounder R. F. on the conning tower, one 37-millimeter Hotchkiss in the military top, and one torpedo launching-tube in the bow.

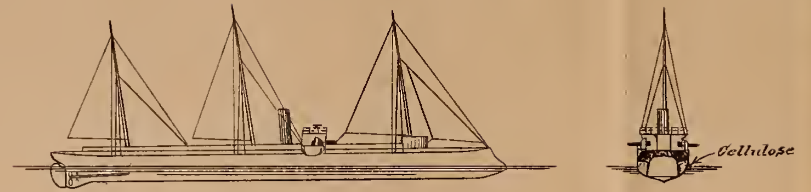
Engines.—Three-cylinder, compound, vertical, inverted, in two separate compartments actuating twin screws; I. H. P., 1,500; speed, 13 knots; normal coal supply, 46 tons; complement, 70 officers and men.

(Scale $\frac{1}{960}$) PLATE V.

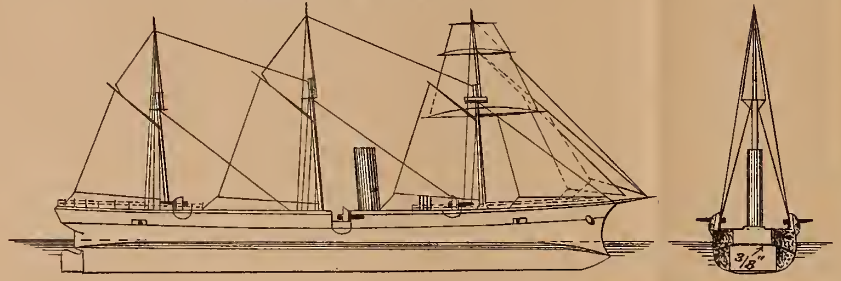
TORPEDO-BOAT, 1st Class.
– Length 125′, Beam 12′ 6″, Draft 6′ 2″ –
19 knots



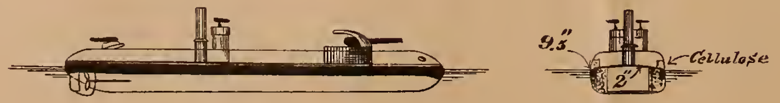
BOMBE
– 321 tons – 18 knots –



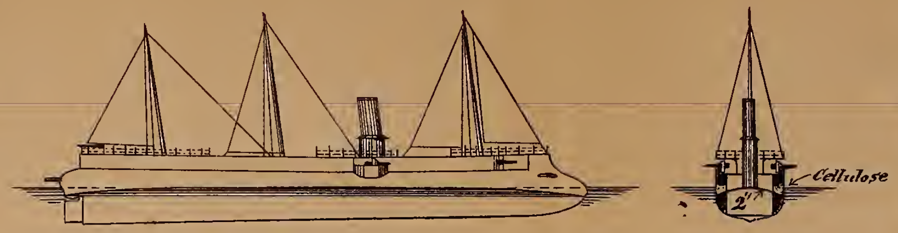
ARCHER
– 1630 tons – 17 to 18 knots –



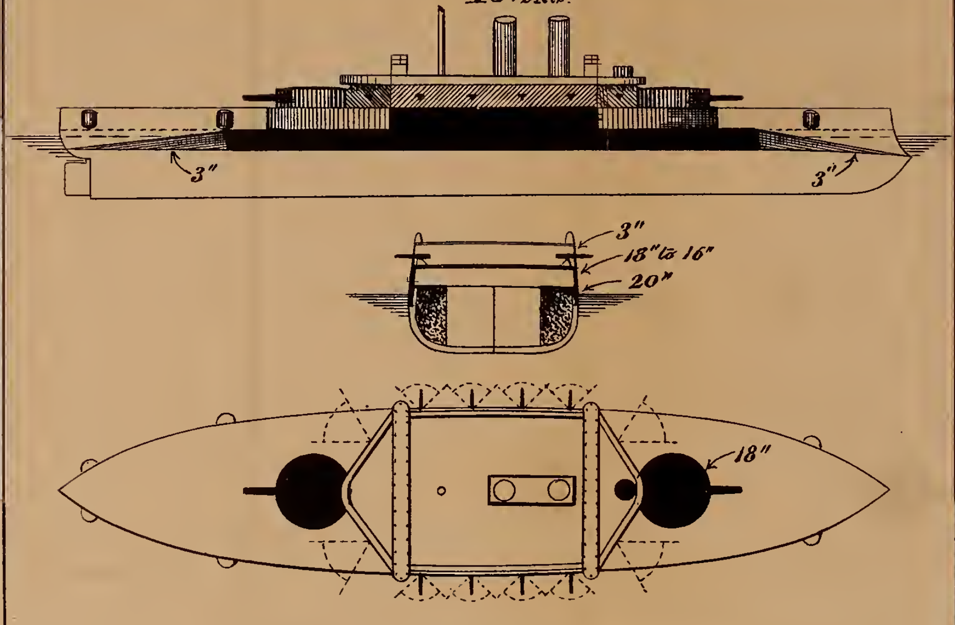
FUSÉE
– 1045 tons – 13 kts. –



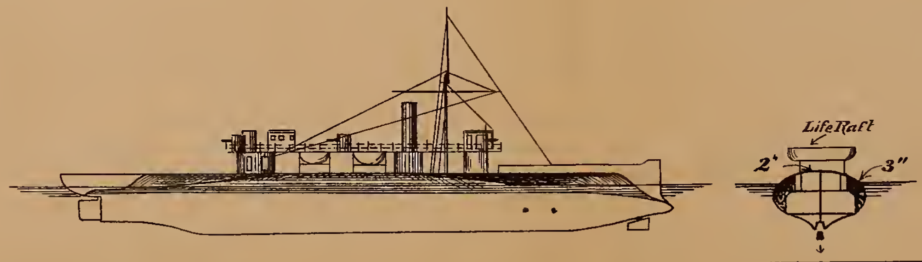
FAUCON
– 1249 tons – 17 kts. –



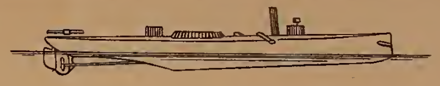
NILE, TRAFALGAR.
– 11,940 tons –
16½ kts.



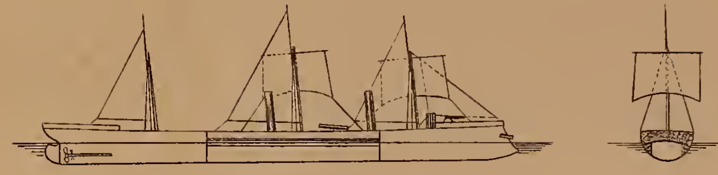
POLYPHEMUS
– 2640 tons, 17.8 kts. –



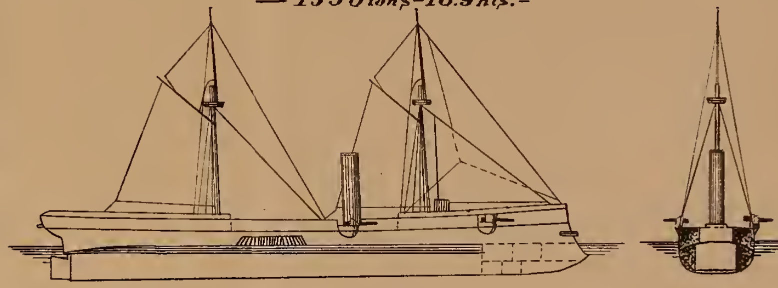
TORPEDO-HUNTER (by Mr. White of Cowes)
– 220 tons –
20 to 21 knots



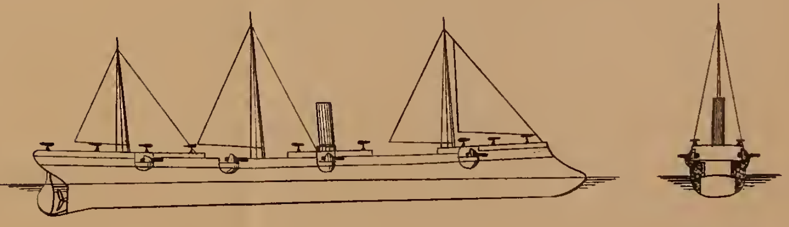
GRASSHOPPER
– 450 tons – 18½ to 19½ kts. –



PANTHER
– 1550 tons – 18.9 kts. –



RUSSIAN TORPEDO-GUNBOAT
– 600 tons, 20 knots. –



PART IV.—NAVAL TACTICS.

Naval tactics and naval architecture are antagonistic in their requirements, and yet they are mutually dependent.

The tactician desires small size, high speed, great endurance, and overwhelming powers of offense and defense, while the architect declares that a compromise only between these antagonistic elements is possible.

Both tacticians and architects differ widely as to the proper proportion of each of these elements in the compromise, and the following extracts from the essay of Sir William Cussack-Smith ("Our War Ships," London, 1886) will give a hint of the possibilities of the future, and the vast field for the display of resource, boldness, genius, and skill on the part of both tactician and architect:

> The same science which keeps inventing and developing new means of destruction is also constantly devising corresponding means of protection, and the equality between the two elements of attack and defense, if at any time momentarily disturbed, is soon re-established.
>
> And in future war operations the "possible loss" will have to be carefully weighed against the "possible gain."
>
> As for any attempt at foretelling the tactics or *modus operandi* of the next naval war, it should be borne in mind that we cannot compel our possible antagonists to fight by "ring rules," and that they may easily upset our most carefully worked out calculations by carrying on the war in some totally unexpected manner.
>
> It is the business of the enemy to deceive us and to lead us to expect something different from what they intend should occur.
>
> Of one thing we may feel sure, and that is that they will avoid attacking us in the manner in which they know we are best prepared to meet them.

In the opinion of a German tactician, naval battles in future will bear a resemblance to combats on shore, torpedo-boats forming the line of skirmishers, whilst the battle-ships will form the supports and reserves.

Other tacticians hold that if torpedo-boats are to be used on both sides as skirmishers, their endeavors must simply be to pass through each other's lines, doing what damage they can with machine guns in passing, and then going on to attack the big game, the battle-ships.

Others declare that the torpedo-boats, to attack with maximum effect, should be held in reserve until the battle-ships are engaged, or that they should do their work under cover of confusion, smoke, or darkness.

Many tacticians hold tenaciously to the opinion that all maneuvering should tend toward ramming, while others declare that, as the whole art of war consists in inflicting a maximum of damage on the enemy while receiving a minimum from him, it would be better to resort to some more clever tactics not quite so decisive at the onset.

Admiral Fremantle, R. N., a conspicuous authority on naval tactics, and hitherto a devoted friend of the ram, now discourses as follows.

(Essay on Naval Tactics, Jour. Royal United Service Inst., No. 133, 1886:)

There are other questions intimately connected with tactics to which I have only time to allude; these are the best size for our fighting ships and the use of the ram. On the first point, I am daily becoming more and more convinced of the importance of speed. If, as I think, the improvements of torpedoes have brought the gun and maneuvering into a more prominent position, I hold that speed must be a primary factor to be considered, for maneuvering power in the open sea means speed in most instances. I cannot, therefore, agree with Sir George Elliot and others who would, in order to keep fighting ships as small as possible, sacrifice speed.

From this point of view I do not see how the size of battle-ships is to be limited if the ships are required at all, and at all events I am on the side of the big ship, as Moreau was on the side of the big battalions. I deny the possibility of reducing this question to a pecuniary standard; if the big ship is to be complete in herself, and to perform the duties demanded of a line of battle ship in old days, she must have size or she will display decided weak points in one direction or another.

That special vessels of various classes intended either for speedy torpedo-vessels, heavy battery ships of slow speed for attacking batteries, small gunboats, torpedo-depot ships, swift cruisers and torpedo-boats of various classes should coexist with the battle-ship goes without saying, but these special ships will frequently find themselves in positions when their speed, or their gun power, or their torpedoes, or their rams are useless to them, and I do not believe that the empire of the seas can be safely intrusted to a fleet of nondescripts forming a sort of "happy family" of contradictory qualities.

There remains the ram, of which I feel inclined to say as an old friend—

"Be to my virtues ever kind,
And to my faults a little blind."

I must, I am afraid, put the ram a little in the background, at least at the commencement of hostilities between fleets; so, in spite of the interesting nature of experiments in maneuvering, circle turning, and other questions of importance in handling a ship, I must cut short this part of my subject with the remark that although my old friend may have fallen somewhat behind, I consider that it is a most important weapon, and that the ram-bow of our ships should be at least as strong as that of the ships of any foreign power.

* * * * * * *

The great tactical question of the day is clearly that of whether big ships and fleets are to continue to exist or whether they are to give place to torpedo flotillas, at least as far as combats in the open sea are concerned, whether, in short, a future naval action is to resemble more or less the engagements of Rodney, Nelson, or Suffren, or whether they are to be a mixed medley or *melèe* of small craft like Actium or Lepanto.

The views in favor of this latter notion have been put forward with much ability by a French writer, M. Gabriel Charmes (see "Revue des Deux Mondes," "La Réforme de la Marine," "Les Torpilleurs Autonomes," &c., M. Gabriel Charmes, 1884-1885), who assures us that ironclads are doomed, that a maritime war will in future consist in the bombardment of defenseless towns by small gunboats, by the ruthless capture or destruction of an enemy's merchant vessels on the high seas by fast cruisers, and by torpedo-boats covering the seas, who will sink and destroy all large fighting vessels.

* * * * * * *

All this will sound "very pretty fooling" to the members of this institution, but as M. Gabriel Charmes professes to found his conclusions on the writings of an ex-minister and the present minister of marine in France, it is worth while to examine shortly the views of these men, who certainly write with much ability and who are occupying or have occupied responsible positions.

M. Gongeard's views ("La Marine de Guerre," 1884) are that everything is in future to depend upon floatability and speed. The iron clad he gives up as no longer a useful tool, but he cannot bring himself to believe that mere torpedo-boats, which he compares to the fire-ships of the seventeenth and eighteenth centuries, will be the fighting vessels of the future. They are nothing but nut-shells, he says, and they will disappear like the fire-ships when sufficient speed is given to other vessels. His conclusion is that a future navy will need a few heavily armed slow ships for attacking forts, and he proposes vessels something similiar to the Scout, of 1,780 tons, with a speed of 20.5 or 21 knots, as "*Navires de haute mer.*"

Admiral Aube's theories, as those of a naval officer, and one who has at present opportunities of carrying them out, are of still greater interest. He is even more cautious than Mr. Gongeard, and rather hints at than directly proposes the abolition of iron-clads.

He believes implicitly in torpedoes and in fast cruisers, while he thinks that in consequence the sovereignty of the seas is rather a word than a fact. He laughs at the rights of war as illogical, and expects that maritime power in default of adversaries evading their blows, will attack all sea-port towns, whether fortified or not, whether peaceful or warlike, will set fire to them, ruin them, or at least will ransom them without mercy. He further sums up in favor of 5½-inch guns, with their range of 7,200 meters, as sufficiently powerful for the above purposes, a conclusion which I shall show later Captain Chabault-Arnault disputes after the experience of the River Min.

It is curious that neither M. Gongeard nor Admiral Aube agrees with Mr. Charmes on the money question, for while the former says that "only rich nations can pretend to have dominion over the seas," the latter says that in "the present day, more than ever, money and boldness are the first elements" of naval victories.

These examples show the drift of intelligent foreign opinion on this important subject, and though in this country no similar views have been put forward in print, I think they are shared by not a few of our young gunnery and torpedo officers, and it is fair to admit that both the screw line of battle ship and the iron-clad first found favor in France.

* * * * * * *

I come now to pure tactics, say 1 to 1 of equal force. This has been well thrashed out on previous occasions. It will generally be decided by the gun, as I hold that, at first at least, ships will mutually avoid the chance of a fatal torpedo shot, and for this reason a ship will endeavor to keep rather before the beam of her opponent if broadside to broadside, or if circling round she could keep either near the enemy's bow or stern, according as her own bow or stern fire was the stronger.

In respect of the use of torpedo-boats in fleet actions, he says:

I do not believe that torpedo-boats will act as skirmishers, or that they would rush past each other to the attack of the ironclads. I think with the author of the "Battle of Port Said" that they will act as a sort of reserve when favorable opportunities offer, always assuming that both fleets are on even terms as regards numbers of torpedo-boats.

I have now simplified my problem by reducing the question to a fleet action between ironclads, the gun being the chief weapon; but I would add here that the ram would naturally be used in self-defense, and torpedoes would be fired as opportunity offered.

To consistency with what I have formerly advocated, I make no claim, except as regards main principles. These are that the admiral must choose the weapon with which he will fight and subordinate his tactics to that choice.

Briefly the status of the torpedo and the ram as influencing tactics and architecture in the future may be summarized as follows:

The torpedo is a weapon of vast possibilities; its destructive powers are so great that no number of failures or accidents can justify a relaxation of effort to perfect it. But means of defense generally keep pace with the development of means of attack, and it is not altogether certain that torpedo-boats will ever pass beyond the importance of convenient auxiliaries.

The ram is the most powerful weapon possessed by a ship, though it is by far the most difficult to use. In this case also the means of defense have kept pace with the means of attack, and the torpedo has to a great extent neutralized the value of the ram.

In a lecture on "the forms of ships" delivered at the Institute of Civil Engineers May 7, 1885, by Sir E. J. Reed, he admitted that great changes in forms and proportions were very desirable in great line of battle ships; for example, a great increase in breadth was necessary in order to economize side armor, and to keep the ram and torpedo at ample distance from magazines and boilers, which should be protected by an inner citadel, so to speak, well removed from the outer one. He further stated that so far was true science from presenting obstacles to these and other important changes, it actually invited those changes, and increase of beam in particular had been shown by Froude to facilitate the attainment of practical invulnerability combined with very high speed.

This statement augurs well for the possibilities in the development of coast-defense vessels of moderate size, light draught, and great powers of offense and defense.

In the address previously mentioned, delivered by Mr. N. Barnaby before the students of the Royal Naval School of Architecture, he said:

> The very heavily armed battle ship has, I consider, only a subordinate part to play, that of preventing in enemys, ships an extension of those armor proof to light guns. What we most want is well armed and fast ships, having their buoyancy assured by a belt, or by an equivalent deck.

France, Germany, and Austria have not laid down any armor clads recently, and if the experiments soon to be conducted on board the English Resistance are any indication, England will again follow France in an important development.

The Resistance is to be arranged for experiments to determine the relative values of cellulose and rubber for water-line belts and of coal armor and bulkheads for protection against torpedoes.

These experiments will be looked forward to with keen interest, and we may eventually see the fast "protected cruiser" adopted as a tactical unit in the line of battle. If so, demands for increased powers of offense and defense will naturally arise, and, according to a natural law, increased size will result until by a circuitous course of development "the powers" generally will have adopted a battle-ship type closely resembling that of the Italia, Sicilia, and others, though perhaps with modified dimensions.

These Italian battle-ships may be regarded as one extreme of a system or type, of which the torpedo-cruiser class is the other extreme, and the

Esmeralda, or "ram-cruiser" class, a medium. There are many advocates of the "ram-cruisers" who even now expect them to take the part of battle-ships, but it is apparent that while the Esmeralda or the Naniwa are masterpieces of science and capable of taking a certain part in any engagement, as cruisers they are offensively unnecessarily strong and as battle-ships defensively too weak.

It is also claimed by those who favor a high forecastle and poop that the Esmeraldas will not be able to work their heavy guns while at full speed in a sea way, owing to want of freeboard at the ends, but this has been provided against in other ships of the same general design, notably in the Mersey, at the expense of heavy end fire, and in the new Spanish cruiser at the expense of increased size.

PART V.—COMPARISON.

If a rigid system of comparison between war ships could be instituted naval tactics and naval architecture or design would both become greatly simplified. But the general impression is that such a system is impossible because experts cannot agree, and it will not be attempted in this paper.

The displacement tonnage, however, represents the capacity of a ship to carry certain weights, and the efficiency of the ship depends upon the apportionment of these weights among the different elements of power.

The principal elements which constitute a vessel's power and fighting efficiency are offense, defense, speed, and endurance.

OFFENSE.

In a rough comparison between the powers of offense of different vessels their torpedoing powers may be disregarded if we consider the torpedo a neutralizer of the ram, and that future actions will probably be decided by the gun. Moreover, all ships carry approximately the same torpedo-battery, and the consideration of torpedoes more properly belongs to the element of defense.

At any rate the battery or gun power of a ship may be regarded as the principal factor in the element of offense, and a standard of comparison between the gun powers of two ships may be taken as a standard of comparison between their powers of offense. Of course steadiness of platform, arising from size, shape, and seaworthiness, enters as a factor in the power of offense and might be included in the consideration of rapidity of fire.

Of all the various standards used in a comparison between guns "energy" is most expressive, and to my mind the fairest standard of comparison between the powers of offense of different ships is that of battery energy, or volley energy, at 1,000 yards.

It is not probable that tacticians will agree to any particular line of action or tactics in engagements, and thus be able to assign unquestioned values to the relative advantages of end-on, broadside, and bow or quarter fire, and, therefore, it may still be held that "all around fire" is the great desideratum in the disposition of guns.

My individual preference is for the preponderance of bow and quarter fire, and it seems to me that in ships designed with turrets *en echelon* too much has been sacrificed to end-on fire. This would also seem to be the impression abroad, if the disposition of guns in the latest designs is any indication.

Undoubtedly the possession of great arcs of fire adds greatly to the efficiency of a battery, and an expression of a ship's battery power would be imperfect without taking the factor of direction or arc into consideration.

Therefore, the sum of the energies at 1,000 yards of all the guns that can be brought to bear in a given direction may be taken to represent a ship's powers of offense in that direction.

In the diagrams (Plate VI) the area of each of the darkened sectors of 30 degrees represents, on a common scale, the sum of all the energies of one volley so determined for typical ships, any gun being considered which can be brought to bear in the sector by a touch of the helm changing the bearing less than 30 degrees.

The combined effect of the diagrams is a fair representation of the respective battery powers of the different vessels therein named, and affords an effective means of comparison between them.

Each diagram also shows effectively in what direction lies the greatest powers of offense of the vessel it represents, and in that way forms a fair comparison between the efficiencies of different arrangements of battery or distribution of guns.

In the diagram representing the offensive powers of the Spanish cruiser, I have counted upon 6-inch guns for the broadside, since it is said she could carry them, and I have also counted upon the ability of her bow and stern guns to fire across the deck to an angle of 45 degrees. It is reasonable to suppose that each of these guns could be mounted so as to fire through an arc of at least 180 degrees, and the diagram expresses the emphasis which such an arrangement would give to her bow and quarter fire.

The diagram of the Italia shows the advantages to offense to be derived from large size and the "deflective" or "protective" mode of distributing armor, and emphasizes the disadvantages in respect of battery efficiency of the echelon arrangement; that of the Renown shows clearly that her best tactics in a fight would probably be to keep the enemy on the quarter; that of the Nile, in comparison with the other battleships, shows what has been sacrificed in offensive power in order to carry a great weight of vertical armor.

To make this comparison more complete the question of rapidity of fire should be taken into consideration, and if a just table of the relative rapidities of fire of different guns were obtainable it would be a simple matter to multiply the energy of each gun by a certain factor representing its comparative efficiency in that respect. Such a table would be very valuable if it included the relative rapidities of fire of the same caliber guns mounted on different carriages, muzzle pivots, and central pivots, manual power, and hydraulic power carriages, for instance.

Such an addition to the diagrams would make the contrast between large ships and small ships still greater, because while the large ships carry certain heavy and slow guns, they also carry a greater proportion of smaller guns in both main and secondary batteries.

The heating effects of slow-burning powder, however, neutralizes the advantages of rapidity of fire to a certain extent, and the advantages of increased bursting effect of the larger shell emphasizes the importance of the larger calibers.

The areas inclosed by the circles represent comparative speed powers, which will be explained a little farther on.

DEFENSE.

A fair expression for the comparative powers of defense of different vessels might be found in the number of tons weight of armor per ton of displacement carried by them for purposes of protection. but this would necessarily involve a modification, by their respective efficiencies, in regard to other elements of defense. In fact a fair comparison of powers of defense would involve considerations of speed, endurance, small size, battery power—particulary of the secondary battery as a means of defense against torpedo-boats—and torpedoes.

It is, perhaps, enough to point out that the efficiency of the defense depends greatly on the arrangement of the armor, and that, until experts can agree upon a comparatively uniform system in distributing the armor, a fair comparison in this respect is impossible.

The diagrams, however, might contain an additional area expression for defense in combination with endurance, at the expense of confusion and want of clearness.

ENDURANCE.

The distance which a ship can cover at most economical speed is a simple and fair expression of her powers of endurance; but a ship not intended for distant cruising may have less endurance than another and still be satisfactorily efficient in that respect. In a cruising ship, if satisfactory sail power can be carried without detriment to the other more important elements of power, it certainly adds greatly to her efficiency.

It will be noticed, however, that the recent battle ships and the latest cruisers, with few exceptions, are sail-powerless, and that the smaller vessels carry meager sail power, but that the respective endurances of all, owing to great improvements in the economy of fuel, are satisfactory, regardless of sail power.

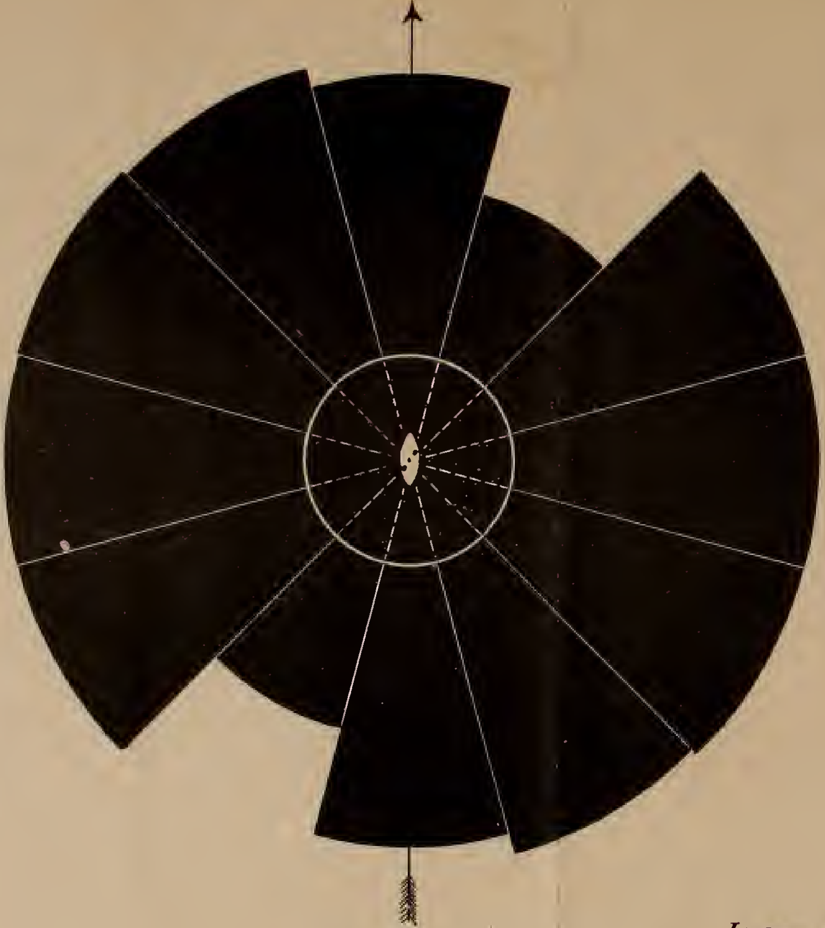
SPEED.

The maximum speed, as determined by the measured mile trial, gives a simple and concise means of comparing the tactical efficiencies of ships in respect of speed in smooth water. And between vessels intended for a service that renders them reasonably sure of having smooth water in which to fight, the question of size does not enter as a factor in speed efficiency.

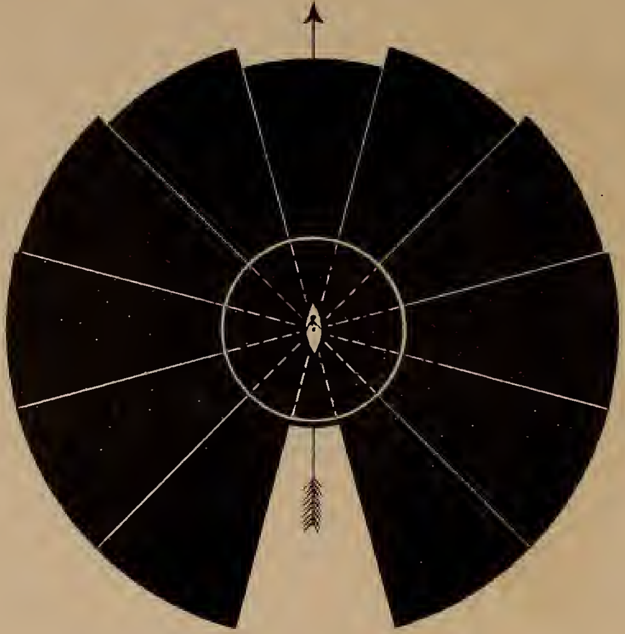
But between ships intended to fight at sea the disturbing or retarding effect of sea-waves operates as a modifying element in their re-

PLATE VI.

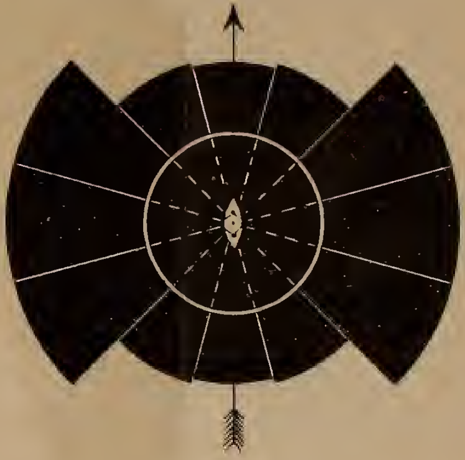
ITALIA



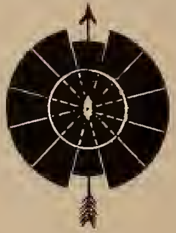
RENOWN



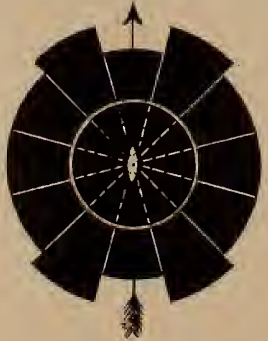
NILE



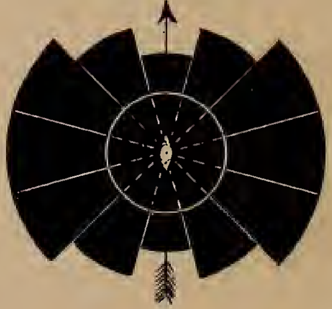
ARCHER



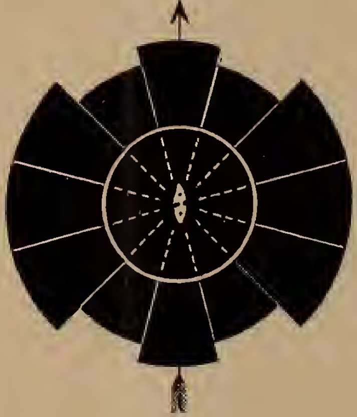
IMPROVED SPANISH CRUISER



NANIWA-KAN



IMPERIEUSE



Substitute the following for 3d paragraph from bottom, page 99:

The "speed energies," as given in the above table, are 100 times too great, and consequently the areas representing, respectively, "speed energy" and "battery energy" in the diagrams are on the same scale.

spective speed efficiencies. Their respective abilities to attain the "maximum trial speed" in their proper spheres of action must be considered. For example, an 11,000 ton Atlantic liner could maintain her "maximum trial speed" under conditions of sea that would seriously retard the Stiletto, although the latter would probably distance the former on the quiet waters of the Hudson. And this power of a ship to attain that speed at sea, or her power to overcome the retarding effects of sea-waves, may fairly be regarded as proportional to her momentum, or what may be termed her speed or ramming energy, $\frac{Wv^2}{2g}$.

In this case, as in that of battery power, a fair unit of comparison is the foot-ton.

The following list gives the comparative speed energies of typical ships in round numbers:

Name.	Speed energy.	Speed.
	Foot-tons.	*Knots.*
Italia	19,190,000	17.6
Renown	12,740,000	16.5
Nile	13,270,000	16.5
Imperieuse	9,743,400	17.2
Naniwa	6,012,000	18.8
Spanish Cruiser	7,870,000	20.5
Archer	2,250,000	17.6

In the diagrams (Plate VI) the area inclosed by the white circumference of the circle at the center of each represents the comparative speed energy of each ship.

For purposes of graphic comparison this area represents the energy of one blow of the ram at maximum trial speed.

t not only serves as a fair means of comparison between the ramming rgies or powers of these ships to attain high speeds at sea, but as the r scale adopted is $\frac{1}{10}$ of that used in delineating the areas of battery er, it will also serve as a means of comparing the ramming energy the battery energy of the same ship and the ramming energy of ship with the battery energy of another, always remembering that n comparing battery energy with ramming energy the ram energy ach case is 100 times greater in area than represented, and that the ery energy, as represented by the area, is the energy of one volley only.

In comparing the battery energy with the ramming energy, it should be remembered in favor of the gun that each darkened sector represents the power of one discharge only from the guns capable of bearing in that direction, and that if two ships should collide at the velocities used in computing the speed areas, both would probably be cushed.

The principal object of the circle areas, however, is to compare the relative efficiencies of ships in respect of sea speed only.

PART VI.—DESIGN.

Of all the problems involved in the designing of a war ship, those relating to the shaping of her hull and the distribution of her weights are the most important.

Upon these depend those qualities which make her either stable or unstable, safe or unsafe, handy or unmanageable, steady or unsteady, and suitable or unsuitable for the working of her guns and other elements of offense.

Correct lines and proportions, or, more properly speaking, correct form and the proper distribution of weights have quite as much to do with making a vessel handy as small size, and fully as much to do with making her seaworthy or fast as large size.

A ship in which the weights are badly distributed in relation to her shape may require more weight of hull to give her the necessary structural strength, more height of freeboard to make her safe, and a greater expenditure of power to develop the required speed.

Twenty-five or thirty years ago we led the world in the art of ship-designing, but since that time we have been obliged to yield the palm to others.

It is generally conceded that our ship-building industries have not received the proper Government encouragement, since the war, to enable us to keep the lead, and one evil result is that we are too prone to give up or to improve upon our old methods of designing, which, though the best in their day, are not suited to the needs of the present.

Some of our best designs, in the days of clipper ships, were not based so much on scientific principles as upon the individual taste and good judgment of our ship-builders. Then the problem was far simpler than now, and the art of designing was, comparatively speaking, almost in its infancy. In those days ships were not designed on paper, but a half model was generally made from which the various measures were taken for the use of the mould loft. The coefficient of fineness and the center of buoyancy, if found at all, were determined in the crudest ways and only after the model or design was completed.

If we would resume our place in the van with nations noted for skill in naval architecture, it is imperative that we gracefully acknowledge our defeat, and endeavor to avail ourselves of the advantages by which our rivals have distanced us.

If ship-building in this country had received the same support and encouragement as in other countries, we doubtless would have maintained the lead; but we have not had opportunities for building and our reputation has had to be bolstered up solely by the prestige of successes achieved before the advent of the revolutionizing era of ship-building in iron and steel.

Experiment lies at the root of all substantial progress.

Every new ship is an experiment in a greater or less degree, and the experience gained by her designers, the skill acquired by every one connected with her building and handling is the principal element in naval progress and national power.

We have had no chances to test the value of original theories; we have been forced to rely upon the meager data furnished by the experience of our rivals, and we cannot expect our skill, so meanly nourished, to be equal to that of others whom we may some day be called upon to fight.

There is doubtless some of our old "rule of thumb and guess-work" method in designing still in vogue, and doubtless many of the ideas handed down by our old school of designers, of whom we justly boast, are still of value; but if in our naval *renaissance*, we would make rapid strides towards the van of progress, we should discard what is bad and retain what is good of our old methods. Formerly the lines of a ship were laid down from a model, but nowadays, as our rivals have discovered, there are advantages in laying down the lines by scientific methods and using the model for other purposes. The model as used abroad, in connection with an experimental tank, renders the finished ship less and less experimental in character.

In his address delivered before the Institute of Civil Engineers, May 7, 1885, Sir E. J. Reed explained the great development which the science of fluid resistance had undergone of late years, due principally to the admirable investigations which had been carried out under the patronage of the English admiralty by the late Dr. William Froude, and subsequently by his son, Mr. W. E. Froude. He also explained the great benefit which had accrued to the Royal Navy owing to the judicious and prompt adoption of Froude's results by the admiralty constructors.

Stress was laid throughout the lecture upon the importance of adjusting the form and proportions of ships, not only to the loads which they have to carry, but likewise to the weight of the materials entering into their structure. It is a common error to judge of the merits of a ship by the relations which exist between her displacement, steam power, and speed, as expressed by formulæ of different kinds, approximations to the theoretical form of least resistance being sought by many designers and all departures from that form being regarded as objectionable. The lecturer pointed out that, on the contrary, no such theoretical form was any true or proper guide for a naval designer, since every change in the average weight of hull necessitated a corresponding change in the form and proportions of the ship, and the great merit of a designer often was that he adopted forms differing widely from the abstract forms of the schools, and presenting a very inferior appearance when put into what are known as "constants of performance."

Mr. W. H. White (see "Manual of Naval Architecture," W. H. White, p. 468) says:

> The problem to be solved by the naval architect is not to determine any exact geometrical form of least resistance of which he can make use in all cases, but in the design of each ship to select the forms and proportions which are compatible with special conditions to be fulfilled, and which make the resistance as small as possible.

If we have a ship possessing certain desirable qualities, all of the essential properties which produce those qualities, and which depend on her shape and distribution of weights, may be calculated from her general dimensions or determined by methods well known to naval architects.

It is now proposed to show that the operation may be reversed, that the giving of desirable qualities to a ship may be made the first steps in design, that the properties which give a ship desirable qualities may be reproduced in ships of all sizes, and, furthermore, that the process, based on sound scientific principles, permits of the greatest possible latitude in the selection of forms to suit special conditions.

By following older methods of ship design many of the essential properties are hidden, or depend entirely on guess-work, until the completion of the design, and perhaps until the completion of the vessel. For example, a vessel of a certain displacement is demanded, and in the absence of any fixed rule for finding the most suitable dimensions corresponding to that displacement, the architect, guided by the designs of finished vessels of about the same displacement, adopts what appears to him the most suitable. When the model is made, or the lines are produced on paper, perhaps the displacement thus calculated is too great or too small, and an approximation process ensues, either by fining away or fulling out the lines, or by the adoption of new dimensions, until the result is considered satisfactory.

Such a method not only involves considerable time and useless labor, but leaves the architect in the dark about the principal properties of his design, such as height of metacenter, until he has made his calculations, with the possibility, after all, of finding his design deficient in desirable qualities. By such a method there is little scope for improving on the forms of existing ships, and it is a common error for the designer, who would ignore the scientific results of more modern methods, to endeavor to improve on existing designs by an increase of length in proportion to beam, the long sharp model being more pleasing to the eye, while the results of model tank experiments might show a broader and shorter ship to be possible, with advantage to speed and considerable gain in handiness, weight of hull, strength of structure, size of target, and cost of construction.

It is certain that the metacentric height in a vessel is the property which influences her qualities for good or bad more than any other, and one of the merits of the method which I am about to describe is that a ship of any size may be designed, with very little labor, sure to possess it to any desirable extent.

Suppose a certain vessel is known to be possessed of excellent qualities and we desire to construct another with greatly increased displacement, possessing the same excellent qualities. As similar bodies are proportional to the cubes of their homologous dimensions, it might be presumed that a simple increase of dimensions following this law would produce the desired vessel. But such is not the case, and by way of illustration we will assume the displacement of the required vessel to be eight times that of another having a metacentric height of 2½ feet. Then by doubling the length, breadth, and depth, and retaining the same coefficients of fineness, all the ordinates and intervals would be doubled and we would get a vessel of precisely the same shape, with its center of buoyancy and centers of gravity of water-lines and cross-sections all in the same proportion. But the metacentric height would be doubled, or 5 feet instead of 2½ feet. A reproduction of the smaller vessel's qualities being the object sought, and a metacentric height of 2½ feet being the principal property by which to obtain them, it is evident that the proportions of the smaller vessel's dimensions would not be suitable for the larger one.

This illustration makes it clear that in taking advantage of the good qualities of any ship, in designing another, the lines of the former are not necessarily copied. A naval architect should doubtless be able to design vessels embodying the good features of others without copying their lines, if for no other reason than that such lines cannot always be had. On the other hand, sufficient data for the reproduction of a vessel's qualities is most always obtainable.

It may be conceived that vessels designed after certain fixed mathematical rules must all be similar in their lines and appearance. But such is not the case, as will be explained hereafter, and it will be shown that the greatest latitude is allowed the designer in the selection of lines suitable for varying conditions of speed and carrying power.

A careful investigation of the method which I am about to describe, as briefly as possible, will make it evident, however, that a certain metacentric height and a certain location of the center of buoyancy is absolutely necessary for the production of certain qualities—upon which a ship's good or bad behavior depends—and that the dimensions to obtain this result can only be obtained with certainty and accuracy through the application of mathematical rules.

An improved method of designing vessels to embody certain desirable qualities, from known geometrical properties.

Let the principal dimensions be expressed as follows:

D=*Displacement*, in cubic feet.
L=*Length* (between perpendiculars),* in feet.
B=*Extreme breadth*, in feet.
H=*Mean draught* (without keel), in feet.

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* In many cases of recent design this would be more properly *length on load water line.*

Thus $D=pLBH$; p being the *coefficient of fineness of displacement.*

The distance of the *center of buoyancy* below the water-line may be expressed as aH; a being some fraction.

The ordinary expression for stability or the height of the metacenter above the center of buoyancy, $\int \frac{2}{3}\frac{y^3dx}{D}$, may be expressed by $\frac{mB^3L}{D}$, in which the fraction m is a certain property of the water-line known as the *coefficient of metacentric stability.*

All the essential geometrical properties may be designated as follows:

D=Displacement, in cubic feet.
p=Coefficient of fineness.
q=Proportion of beam to length, or $\frac{B}{L}$.
a=Center of buoyancy below L. W. L.
(Expressed as a fraction of H.)
m=Coefficient of metacentric stability.
h=Metacenter above L. W. L., in feet.

Then we have—

$$\int \frac{2}{3}\frac{y^3dx}{D}=\frac{mB^3L}{D}=h+aH,$$

And substituting $D=pLBH$ in the above, we have—

$$B=\sqrt{\frac{Hp(h+aH)}{m}} \qquad (1)$$

Again—

$$B=qL \qquad (2)$$
$$D=pLBH.$$

Whence—

$$B=\sqrt{\frac{qD}{pH}} \qquad (3)$$

Equating (1) and (3),

$$\frac{Hp(h+aH)}{m}=\frac{qD}{pH}$$

Or,

$$H^3+\frac{hH^2}{a}=\frac{mqD}{ap^2} \qquad (4)$$

The first step, therefore, is the determination of H from (4), the equation of a solid, and if the designer had no conception of its value the task would be difficult. However, the approximate draught of water suitable for the given displacement D would be known by a novice even, and a few substitution trials in the formula would indicate the two whole numbers between which its exact value would lie. Then substituting for H (the lowest whole number + x), the equation may be solved for x by neglecting x^3, which is always too small a fraction to be worth retaining.

Having H, the values of B and L may be readily found from the other simple formulæ, after which the lines may be laid down.

The process will be better explained by the following calculations, in which the requisite data are taken from a small gunboat designed by Assistant Constructor R. Gatewood, U. S. Navy. This vessel was not designed according to the methods herein described, but being intended to pass through the Erie Canal, the largest possible dimensions which the locks would admit of were adopted. After the lines were laid down the displacement and other data were calculated by the usual methods, the metacentric height being a natural consequence of the dimensions restricted by the locks.

$D=128.65$ tons, or 4,503 cubic feet;
$q=0.1804$;
$p=0.448$;
$a=0.40$;
$m=0.042174$;
$h=2.50$;

Substituting the above values in (4)

$$H^3+\frac{2.50}{0.40}H^2=\frac{.042174\times0.1804\times4503.}{.40\times0.200704}$$

$$H^3+6.25H^2=426.47$$

It is readily perceived that H lies between 5.0 and 6.0, or

$$H=5+x$$

$$(5+x)^3+6.25(5+x)^2=426.47$$

$$281.25+137.5x+21.25x^2+x^3=426.47$$

Neglecting x^3, we have—

$$x^2+6.4706x=6.834,\text{ or }(x+3.2353)^2=17.301$$

$$x=.9241,\text{ or }H=5'.9241=5'11''$$

$$(3)\qquad B=\sqrt{\frac{qD}{pH}}=\sqrt{\frac{.1804\times4503.}{.448\times5.92}}=17'.5$$

$$(2)\qquad L=\frac{B}{q}=\frac{17.50}{.1804}=97'.0$$

These dimensions agree with those on which the vessel was designed, even to the smallest fraction of an inch, and in proof of it—

$$D=pLBH=.448\times97\times17.5\times5.92=4502.1\text{ cu. ft.}$$

To verify the correctness of the coefficient of stability, we have

$$m=\frac{(h+aH)D}{B^3L}$$

Or

$$m=\frac{21916.22}{519859.28}=.04216+{}^{*}$$

---

[*] For the sake of better illustration, logarithmic tables have not been used in these calculations.

Now, it is an easy matter to tabulate p, q, a, m, and h for all ships, and to associate them with the record which it is only given to "those who go down to the sea in ships" to keep.

The relations between a, m, and h are very significant, likewise very easy to understand, and one of my objects in dwelling upon this subject is to point out to sea-officers the vast importance of keeping an intelligent record of observations on the behavior of ships at sea. The most elementary knowledge of the relations existing between the opposing forces of buoyancy and gravity will enable officers to make intelligent and valuable observations of the effect of waves on the behavior of the ships in which they cruise, and thereby to assist the architect in giving us good qualities only in the future ships with which we expect to be so intimately associated. Such observations would go far towards breaking the monotony of a watch while lying to in a gale.

To show at once the relations existing between length, breadth, and draft, and the latitude allowed a designer in working by this method, let us refer again to equations (4) and (2), from which we get

$$q=\frac{ap^2}{mD}\left(H^3+\frac{h}{a}H^2\right)=\frac{B}{L} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

An examination of (5) shows the importance of the factor q, it emphasizes the value of model tank experiments, and shows that to retain the same displacement, coefficients, and stability, when H is increased $\frac{B}{L}$ approaches unity; or, in other words, to retain the same displacement, coefficients, and stability, an increase of draft requires that the length be decreased in proportion to beam, or a decrease of draft entails a proportional increase of length to beam.

It also shows that when any one of the three dimensions is restricted or fixed there is only one set of dimensions which will fulfill the conditions of displacement, stability, and fineness, and furthermore, that there is only *one set of dimensions* which will fulfill these conditions if the proportion of length to beam is adhered to.

In fact, in this simple formula the architect can see at a glance the effect of any change in displacement, dimensions, or coefficients which he may contemplate in his design, and one of the most striking features which it displays is the value of increase of beam and deep draft to economy in the design of war ships.

Let us now suppose that the 128-ton gunboat has been built and found to develop excellent qualities, and that we wish to lay down another of the same displacement which shall embody the same fineness and stability, but for which the draft is restricted to 5 feet.

Substituting $H=5.00$, and the values of a, m, p, and D as previously given, in equation (5), we have—

$$q=\frac{.4\times\overline{.448}^2}{.042174\times4503}\left(125+\frac{2.5}{.40}25\right)=.11789$$

Substituting this in (3)

$$B=\sqrt{\frac{.11789\times4503}{.448\times6}}=15'.46=15'\ 5\tfrac{1}{2}''$$

Substituting this in (2)

$$L=\frac{15.46}{.11789}=130'.$$

To verify these dimensions for the displacement,

$$D=.448\times130\times15.46\times5=4503 \text{ cubic feet.}$$

And to verify the coefficient of stability,

$$m=\left(\frac{h+aH}{B^3L}\right)D=\frac{21916.22}{519859.28}=.042174, \text{ as before.}$$

Having found the desired dimensions, we will now explain how the lines for the given displacement may be obtained by a skillful designer in a period of time much shorter than by any of the methods given in the standard works of reference. And the example will serve to show, furthermore, that the underwater lines of any vessel may be very nearly reproduced from a knowledge of no more data than D, a, h, m, p, q, the horizontal position of the center of buoyancy, and the respective coefficients of fineness and centers of gravity of the load water-line and midship section.

DELINEATION OF THE DESIGN.

After the general dimensions for a proposed ship have been calculated, as above, and the necessary freeboard and sheer have been determined, the first step is to describe on paper the sheer plan. Then follows the midship section, for which the greatest breadth and width of keel are known and for which 3 intermediate ordinates are calculated, thus giving 5 points through which to sweep in the line. The next step is to shape the load water-line, for which the greatest breadth and two endings are known, and the calculation of 4 additional ordinates, giving 7 points in the curve, is sufficient to define the line. The areas for the after and forward ¼ and ⅛ cross-sections are then calculated, from which their ordinates may be found by a process similar to that used in calculating the ordinates of the midship section. It is, however, quite as satisfactory, and a saving in time, for a practiced designer to run these cross-sections in by the eye, the greatest breadth being taken from the plan of the load water-line, the width of keel being known and the depth being taken from the sheer plan.

The cross-sections having been completed, additional water-lines and section lines can be run in and complete fairness of the design may thus be insured.

Without more than the meager data which we have assumed to be sufficient, each of the successive steps can be performed by an experienced designer in a comparatively short time with a certainty of attaining the required results; and the method makes it possible for those of little experience, even, to perform the work with the greatest success.

THE MIDSHIP SECTION.

The coefficient of fineness of the midship section must stand in a certain proportion to the coefficients of fineness of the displacement and of the L. W. L., and while a small variation in the former may be made for a fixed displacement, this variation cannot exceed certain limits, and must naturally effect the coefficient of L. W. L. *in the opposite direction.* For example, in the case before us, as the coefficient of fineness of the displacement is very small, the coefficient of fineness of midship section may be tolerably large, the coefficient of fineness of the load-water line remaining small, and any decrease in the coefficient of the midship section will therefore necessitate an increase in the coefficient of fineness of the L.-W. L.

The coefficient of displacement = coefficient of midship section × coefficient of Mean W. L., and it naturally follows that the coefficient of L. W. L. depends on the coefficient of displacement and coefficient of midship section. The exact proportion which the L. W. L. should bear to the Mean W. L. is a matter of experience on the part of the designer, and admits of slight variations. If the L. W. L. is full in proportion to the Mean W. L. the cross-sections will be comparatively sharp in the bottom; if it is fine, the sections will be comparatively full in the bottom. The designer must know what sections he prefers, and the model-tank is a short road to success in this respect. Any slight change in the L. W. L. will naturally give a small variation in the metacenter, and the coefficient of stability m, being a certain property of the L. W. L., always indicates the sharpness of the latter. To get this exact at once requires a deal of experience on the part of the designer in selecting the proper coefficients of midship section and L. W. L. for a given coefficient of displacement; but it can be done by the less experienced by approximation trials, and a tabulation of these coefficients for existing ships may be made to serve as a guide.

The determination of the coefficient of fineness of midship section is thus seen to be an important step in the process, but enough has been said to indicate how it is accomplished. The determination of the center of gravity of midship section is a simpler matter, for as the center of gravity of a square or rectangle is a fixed point at one-half of the depth, and the center of gravity of a triangle at one-third of the depth, so has every fair curved line between the two—at least such as is used for cross-sections—its center of gravity very nearly fixed in proportion to its coefficient of fineness, any possible variation being so small as to be hardly perceptible.

Thus having fixed upon the coefficient of midship section as .82 and the center of gravity of midship section as 0.43 H, we have,

Area of midship section $=15.46\times5.00\times.82=63.38$ square feet, and center of gravity $.43\times5.00=2'.15$ below L. W. L.

The ordinates are found as follows:

A=area of midship section=63.38
H=mean draught=5.00
B=extreme breadth=15.46
d=half the width of keel=.33
r=coefficient of fineness of midship section=.82
a=center of gravity below L. W. L. (expressed as a fraction of H)=.43

Middle ordinate:

$$\frac{\frac{3}{4}A}{H}-\frac{B+2d}{7.00^*}=9.51-2.30=7.21=f$$

Upper $\frac{1}{4}$ ordinate:

$$\left[\left(2\tfrac{1}{4}-3a\right)r-\tfrac{3}{16}\right]B-\tfrac{1}{4}f+\tfrac{1}{4}d=[(2.25-1.29)\ .82-0.1875]\ 15.46-1.8+.08\ =7.55$$

Lower $\frac{1}{4}$ ordinate:

$$\left[\left(3a-\tfrac{3}{4}\right)r+\tfrac{1}{16}\right]B-\tfrac{1}{4}f-\tfrac{1}{2}d=\ [(1.29-.75)\ .82+.0625]\ 15.46-1.80-0.16=5.85$$

To verify the work, we will calculate from these ordinates the area and the center of gravity by Simpson's rules, as follows:

W. L	7.73	1	7.73	0	0.00
Upper $\frac{1}{4}$	7.55	4	30.20	1	30.20
Middle	7.21	2	14.42	2	28.84
Lower $\frac{1}{4}$..............	5.85	4	23.40	3	70.20
Keel	0.33	1	0.33	4	1.32
			3)76.08		)130.56
			25.36		1.716
Interval, $\frac{5.92}{4}$			1.25		1.25
$\frac{1}{2}$ area....			31.70		2.145 center of gravity below L. W. L.
			2		
Area			63.40		

---

* This varies according to the coefficient of fineness.

THE LOAD WATER-LINE.

As has been stated, a slight variation only can be made in the coefficient of fineness of L. W. L. without seriously affecting the metacenter or other properties. The location of its center of gravity permits of greater variation, and in all cases it falls somewhat aft of the center of buoyancy, due to the fact that the after sections generally have a **V** shape, while the forward sections are usually fuller towards the keel, or nearer a **U** shape.

With a coefficient of fineness of the displacement of .448 and a coefficient of midship section of .82, the coefficient of fineness of L. W. L. would be about .66, and its center of gravity about .017 L aft of the middle of length, for the given position of the center of buoyancy. Hence the area $=130.\times15.46\times.66=1{,}326.46$ square feet; and the center of gravity $=130\times.017=2.21$ feet aft of middle.

CALCULATION OF THE ORDINATES.

Ordinate at after $\frac{1}{4}$ length:

$$\tfrac{1}{2}B\times.810=7.73\times.81=6.26=g$$

Ordinate at forward $\frac{1}{4}$ length:

$$\tfrac{1}{2}B\times.702=7.73\times.702=5.43=k$$

Ordinate at after $\frac{1}{8}$ length:

$$(1\tfrac{1}{2}+4a)rB-(\tfrac{1}{2}B+\tfrac{1}{8}k+\tfrac{5}{8}g)=(1.5+.068).66\times15.46-(7.73+.68+3.90)$$
$$=3.69$$

Ordinate at forward $\frac{1}{8}$ length:

$$(1\tfrac{1}{2}-4a)rB-(\tfrac{1}{2}B+\tfrac{5}{8}k+\tfrac{1}{8}g)=(1.5-.068).66\times15.46-(7.73+3.40+.78)$$
$$=2.70$$

These ordinates, including the ends, give 7 points in the curve, which are sufficient to strike in the W. L.

TRIAL BY SIMPSON'S RULES.

0.00	½	0.00	2	0.0
3.69	2	7.38	1½	11.07
6.26	1½	9.39	1	9.39
7.73	4	30.92	0	20.46
5.43	1½	8.14	1	8.14
2.70	2	5.40	1½	8.10
0.00	½	0.00	2	0.00
		3)61.23		16.24
		20.41		20.46
Interval,		32.5		61.23)4.22
		663.32		0.069
		2		32.5
		Area=1326.64		2.24 center of gravity aft of middle.

THE ONE-FOURTH AND ONE-EIGHTH SECTIONS.

The location of the center of buoyancy, in a horizontal direction, has very little influence on the displacement and the metacenter; it is a matter open to the judgment of the designer which progressive model-tank experiments cannot fail to enlighten. Of course the location of the center of gravity of the L. W. L. depends to a great extent on the position of the center of buoyancy, but by this method the latter is always adopted first and the center of gravity of the L. W. L. is regulated by it.

We may, therefore, assume the center of buoyancy as situated at .0054 L, which fraction we will denote by a'.

The forward $\frac{1}{4}$ section:

$$[(\tfrac{3}{4}+3a')p-\tfrac{1}{8}r']B\,H=[(.75+.015).448-.1025]77.30=18.57=F$$

Area of after $\frac{1}{4}$ section:

$$\tfrac{3}{4}(p-\tfrac{1}{8}r')BH=(.75\times.448-.1025)\,77.30=18.05=A$$

Area of forward $\frac{1}{8}$ section:

$$[(1\tfrac{1}{2}+2a')p-\tfrac{1}{2}r']BH-(\tfrac{1}{8}F+\tfrac{5}{8}A)=[(1.5+.01).448-.41]77.30-(3.12+15.15)=6.98$$

Area of after $\frac{1}{8}$ section:

$$[(1\tfrac{1}{2}-2a')p-\tfrac{1}{2}r']BH-(\tfrac{5}{8}F+\tfrac{1}{8}A)=[(1.5-.01).448-.41]77.30-(11.60+2.26)=6.05$$

TRIAL FOR THE DISPLACEMENT.

0.00	½	0.0	2	0.0
6.05	2	12.10	1½	18.15
18.05	1½	27.08	1	27.08
31.69	4	126.76	0	45.23
18.57	1½	27.85	1	27.85
6.98	2	13.96	1½	20.94
0.00	½	0.00	2	0.00
		3)207.75		48.79
		69.25		45.23
		Int. 32.50		207.75)3.56
		½ D 2250.63		.0172
		2		Int. 32.5
Displacement, 4501.26				0.56 center of buoyancy abaft middle.

TRIAL FOR HEIGHT OF METACENTER.

$$\frac{mB^3L}{D}=\frac{.042174\times 15.46^3\times 130}{4502.}=4.50$$

$$\begin{array}{rl}CB \text{ below L. W. L.}= & 2.00\\ \text{Metacenter above L. W. L.} & \overline{2.50}\end{array}$$

Exactly the same as in the case of the gunboat of same displacement and 5′ 11″ draught of water.

Three properties of the cross-sections are now known, viz., their greatest breadths on L. W. L., their depths from L. W. L. to keel, and their areas; and it is impossible for the designer to go astray in choosing his curves. He must adhere to the areas as calculated, but he has some latitude in fixing the curves, which, however, is not very great. As soon as the cross-sections have been laid on the body plan, a few water-lines must be run in on the half-breadth plan, and one or two bow and buttock lines should be described on the sheer plan; if these prove to be fair, the sections are correct; if not, they must be faired up and the cross-sections changed to correspond with them.

The ordinates for the different cross-sections could be found by a process similar to that used for the midship section, but it is preferable for the designer to run the sections in according to his own taste, the result of experience, taking care, however, to retain the areas of the sections the same as calculated.

After the calculations have been made it is desirable to lay down a "curve of areas" of the cross-sections, and if this curve is not fair, or not exactly according to the designer's taste, it may be faired up and the areas correspondingly corrected. Such corrections, however, will necessarily be very trifling, but if anything be taken from the curve in one place it must be added in another near by, or, in other words, the differences must be split so as to retain the proper displacement.

The great advantages of this method, not possessed by any other, are (1) *simplicity*, (2) *rapidity*, (3) *certainty* of producing desirable qualities and accurate results, and (4) *adaptability* for making the lines to conform to the developments of model-tank experiments, and for introducing novelty in design.

The necessary calculations are few and easy, and a designer of experience can, with absolute certainty of results, make them all as well as the complete drawings, including the sheer, half breadth, and body plans, in from one and a half to two days.

It may be conceived that vessels designed by this method are necessarily alike or similar in appearance, but it is clear that any slight deviations in the locations of centers, the slightest increase or decrease of metacentric height, gives different general dimensions, and as the coefficients of water lines and midship section are more or less open to the designer's judgment, without making any essential difference in the final results, it evidently admits of the greatest possible latitude for taste and improvement in design.

This method is of great value also in testing the stability of cases in which the general dimensions are adopted at random. For example, given a length of 300′; beam, 46′; mean draught, 20′; and coefficient of fineness of displacement, .52, all adopted at random or forced by restricted conditions, to ascertain whether such dimensions will give the required stability.

The product of these dimensions and the coefficient gives a displacement of 4,100 tons, or 143,500 cubic feet, and with such a coefficient the center of bouyancy would be about 0.41 *H** below the L. W. L., or—

$$0.41 \times 20 = 8'.2 = \text{center of buoyancy below L. W. L.}$$

Experience and comparison of existing ships show that for a coefficient of fineness of displacement of .52, the coefficient of stability is about .043. †

Substituting in the expression for stability—

$$m\frac{B^3L}{D} = \frac{.043 \times \overline{46.}^3 \times 300.}{143{,}500.} = 8.75 \text{ metacenter above C. of B.}$$

$$\underline{8.20 \text{ C. of B. below L. W. L.}}$$

$$\text{Metacenter above L. W. L.} = .55 \text{ feet.}$$

Showing that to insure stability the center of gravity would have to be very low down. As in ordinary sea-going vessels the height of metacenter usually ranges from 1½ feet to 3 feet above L. W. L., and in all "protected" ships the center of gravity is very near the water-line, it shows the metacentric height of the case under consideration insufficient.

The foregoing is merely an outline sketch of a method which is worthy of a clearer and more extensive treatment than I have been able to give it, and for my conception of which I do not wish to claim any originality. Let it suffice, however, to say that I have given it a careful investigation, that I have seen it used with surprising success, and that my estimation of it is strengthened by the indorsement of Assistant Constructor R. Gatewood, U. S. N., who states that he has used it very successfully and knows of no better method of dimensioning vessels or recording the geometrical properties of their forms.

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*This would range between .38 *H* for the sharpest, and .44 *H* for the fullest shapes. For ships having the same displacement and coefficient of fineness the position of the center of buoyancy may vary a little; that is, in a ship having full sections and fine water-lines it would be a trifle lower than in a ship of the same displacement and fineness, but having finer sections and fuller water-lines.

† This varies for all ships between .038 and .055, depending on the coefficients of fineness of the displacement and the L. W. L.

THE PRESENT USE OF MODELS.

As before stated, a careful analysis of equation (5) or—

$$\frac{ap^2}{mD}\left(H^3+\frac{h}{a}H^2\right)=\frac{B}{L}$$

shows at a glance the effect of any change in the dimensions and coefficients on the model of a ship. It proves conclusively that "the great problem in ship design is not to seek any exact form of least resistance or any particular set of lines to suit all cases, but in the design of each individual ship to select the forms and proportions which will at once be compatible with the special conditions to be fulfilled, and make the resistance as small as possible."

On this subject Mr. White* continues as follows:

> Even when thus narrowed the problem is one of considerable difficulty, mainly because of our ignorance of the laws which govern the wave-making resistance. At present only a few of the more important conditions influencing wave-making have been determined, and these rather in a qualitative than a quantitative fashion. The determination of the resistances of ships is therefore necessarily a matter of experiment in the present state of our knowledge; and, apart from experiments, great uncertainty must always attend estimates of the resistances of new types of steamships, as well as of the engine power required to attain certain speeds. This is especially true of types in which novel forms or proportions are introduced, or in which the speeds to be attained lie outside the range of previous experience. * * *
>
> Radical changes can only be made with any certainty on the basis of careful experiments, and such experiments are best conducted on models according to the system introduced by the late Mr. Froude. * * *
>
> Since his lamented death the work has been continued on behalf of the Admiralty by his son, Mr. R. E. Froude. Similar works have been established in Holland, and attempts in the same direction have been made in France and Italy. The establishment at Amsterdam is conducted with marked ability by Mr. Tideman, chief naval constructor, who has published an interesting account of a long series of experiments made on models of different types of ships. At this place were made the experiments upon which the design of the yacht Livadia (built on the Clyde for the Emperor of Russia) was based. This remarkable vessel is 230 feet long, 150 feet broad, and of 8 to 9 feet draught, her form and proportions departing so considerably from those of any preceding vessel that it is difficult to conceive how any estimate of the engine power could have been made independently of such experiments.

This experimental method of comparing the merits of various forms is being extended to the merchant marine, Messrs. Denny & Brothers, of Dumbarton, Scotland, having established a model tank, with improvements in the registering apparatus, and several other ship-building firms, recognizing the economy of such a policy, are contemplating similar additions to their resources.

The experiments made by this use of models during the last 23 years—the period of our slumber in ship-building affairs—have resulted in most valuable contributions to knowledge respecting the laws of fluid resistance and wave motion. Indeed all the theories and established principles upon which the forms of ships are now determined abroad are the results of such investigations.

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*Manual of Naval Architecture, p. 468.

Mr. Froude discovered that for two vessels of similar forms, for example, a ship and her model, the corresponding speeds are to one another as the square roots of their homologous dimensions, and at these speeds the resistances are as the cubes of the homologous dimensions, subject to a certain correction for skin friction; or if l and L be the respective lengths, v and V the respective speeds—

$$\frac{V}{v}=\sqrt{\frac{L}{l}} \text{ and } \frac{R}{r}=\left(\frac{L}{l}\right)^3$$

Thus the relation between the ship and her model is established, and in a laboratory devoted to model-experiments nothing is left to imperfect observation, no chance is permitted of error occuring anywhere. Everything is automatic and self-registering. When once the small engine which draws the paraffine model through the water in the tank is put in motion, there is nothing to do but wait until the conclusion of the trial, and read the data inscribed with faultless precision by the recording apparatus.

The apparatus is simple, and, considering the economy attending its use, is of inestimable value.

Wave motion, the rolling of ships, the efficiency of propellers, and other kindred subjects of importance to the naval service and shipbuilding industries of the country, may also be investigated by this use of models, and if we would avoid fostering a system of false economy in ship design it is imperative that we establish at least one such laboratory in this country.

Mr. Froude's original success was due in a certain degree to the quietness of his little retreat at Torquay, where he was undisturbed by the idly curious, and I would recommend a quiet site, within easy reach of Washington, for a similar laboratory in this country.

THE DEVELOPMENT OF THE MODERN TORPEDO-BOAT.

By Lieutenant SEATON SCHROEDER, U. S. Navy.

The history of the torpedo-boat begins in 1776; the story of its development in 1863. The long period of comparative rest that followed the distracting wars of the early part of this century was fatal to rapid progress in the branch of warfare inaugurated by David Bushnell, and prosecuted with equal skill by Robert Fulton. The latter, branching off in the direction of surface boats, entered a path which, after being abandoned for fifty years, was resumed with no greater improvement than was naturally coincident with the advance in the industrial arts. The efforts and successes of these two American pioneers are a matter of history, and in subaqueous navigation opened a field for many inventors.

It may be noted with interest that in America, in 1861, as in 1776 and 1800, thought was first turned, for offensive warfare, in the direction of submarine boats. Passing over an unsuccessful attempt early in the civil war to produce a serviceable vessel to be used like a diving-bell, the first notable step taken by the Confederate torpedo corps was in 1863, when a boat was built at Mobile to operate either under water or at the surface. This boat, which during its career caused the death of four crews, numbering in all about thirty men, was of galvanized iron, 35 feet long, 3 feet wide, and 5 feet deep, shaped like a fish; it was propelled by a hand propeller worked by eight men, guided by horizontal and vertical rudders, and fitted with water-tanks which could be filled or emptied so as to increase or decrease the weight, and so regulate the submersion. The workmanship is said to have been good, and the lines fair, and a speed of 4 knots was attained. The offensive power consisted of a buoyant torpedo towed astern and dragged under the bottom of the enemy's vessel. At the first trial she became unmanageable, sank, and drowned all nine on board. Shortly afterwards, having been raised, she was taken to Charleston, and while in tow one day was capsized, drowning three more men. Finally, Mr. Hunley, the owner, took charge, and with eight men started to go under a vessel in the harbor, when she dived with such velocity as to stick her bow in the mud, and again all hands were drowned. After that she was only used as a surface boat, and, as such, was sunk for the fourth and last time in the successful attack by Lieutenant Dixon against the Housatonic, February 17, 1864.

Submarine operations experienced a momentary check, but in the leisure times of subsequent peace the subject was studied assiduously, and the productions of Nordenfeldt, Holland, Goubet, Tuck, Waddington, and others, testify to the ingenuity and thought that have been devoted to it.

Whatever the future may bring forth, however, the modern torpedo-boat is a surface-floating vessel, and its development may properly be said to have begun in 1863, when Fulton's project of "placing a torpedo under a ship in defiance of her powers of resistance" was revived in the United States, and a successor to Berrian's turtle-shaped vessel of 1812 was found in the Confederate "Davids."

These craft, which took their name from the first of their class, were built in Mobile, Savannah, and Selma; they were cigar-shaped, 40 to 60 feet long, about 7 feet broad, driven by a screw-propeller with steam for the motive power, and could make about 7 knots in smooth water. They carried spars about 12 feet long, rigged out ahead, and fitted with copper torpedoes containing 50 to 70 pounds of powder, and mechanical fuses to explode them.

Several fast four-oared pulling torpedo-boats were also built at Mobile during the latter part of the war, but were never used, although in the opinion of the Confederate officers, after their experience with the Davids, they promised well.

On the Union side the field for the use of torpedo-boats was small. A number of ordinary steam launches, with good speed, and carrying 12-pound howitzers, were fitted in 1864 with the Wood and Lay torpedo, and sent to the different blockading squadrons, where they served as picket-boats; but the only occasion of one being used for offensive torpedo operations was in the night of October 28, 1864, when Lieutenant Cushing blew up the Albemarle in the Roanoke River.

There were in all seven attacks by torpedo-boats during that war. In every case the weapon was a spar-torpedo of some kind. Two of the attacks were completely successful, but at the cost of loss of life, in both instances by drowning alone. In two others the assailants succeeded in exploding their torpedoes alongside, but with only partial effect. The Memphis and Wabash slipped their chains and escaped; in the case of the Octarora, anchored in shallow water, the David ran her torpedo into the mud and could not explode it, but succeeded in retiring out of action. After this last attack fast-pulling guard-boats were kept on duty, their plan of action being to lasso the smoke-stacks of the Davids and carry them by boarding.

In retrospect, it appears that while the boats were slow, as compared with those of to-day, unprotected against musketry or falling water, and fitted with comparatively primitive torpedoes and fuses, the offense was on an equal footing with the defense. The two entered the arena together, and have advanced hand in hand since then. And while the progress of each has been such that the attack of 1864 would be powerless against the resistance offered in 1886 by electric search-lights, swift counter-boats, machine artillery, wire nettings, minute subdivision of hulls, &c., and that, on the other hand, the boats of to-day could not possibly be repelled by the defense of 1864, yet the conclusions drawn from the circumstances and results of those seven attacks were of vital importance in guiding future design; to this day they remain unchallenged and, practically, unmodified, except that the want of each quality called for has been more or less intensified. It was shown first and foremost that the attacking boat (using a spar-torpedo) must be protected from the column of water raised by the explosion; both Cushing's and Dixon's boats when raised were found to be uninjured, and therefore must have been sunk by the wave. Speed, noiselessness, and non-visibility were also considered necessary factors of success. It seemed proven that musketry could not be relied on to disable attacking boats after they reached a point near enough to be seen at night; but as torpedo warfare was foreseen otherwise than as a forlorn hope, it seemed imperative to afford protection to the crew and machinery against breech-loading small-arm fire. The spar-torpedo being the only one devised for use from a boat, the vexed question of carried *vs.* automobile had not arisen to perplex the naval mind.

While the Wood-Lay torpedoes were being fitted to the Federal steam launches, work was begun on an armored torpedo vessel, named the Spuyten Duyvil, designed also by Chief Engineer W. W. W. Wood and Assistant Engineer John L. Lay. The length of this vessel was 84 feet 2 inches; beam, 20 feet 8 inches; draught when equipped, 7 feet 5½ inches, which in action (sinking tanks filled) was increased to 9 feet 1 inch; displacement, 207 tons. The plating was 5 inches thick on the sides, 3 inches on deck, and 5 inches round the pilot-house; speed about 5 knots. The torpedo to be used was the same as those of the launches, except that it held 60 pounds of powder instead of 40. The spar, which was of malleable iron, was thrust through a port in the bow just above the keelson, and had an iron rod running through the center which threw off the torpedo when rigging in the spar.

The two serious defects in this vessel were the low speed and the impossibility of firing the torpedo with headway on account of the immediate danger of self-destruction by running over it. The latter was the defect of the torpedo rather than of the boat, and was remedied in subsequent improved designs by arranging the torpedoes so they could be projected clear of the ship's side when she was in motion, and be fired by electricity.

The Spuyten Duyvil was a formidable vessel as compared with her contemporaries, owing to her size and protection against falling water and small-arm and even artillery fire. Subsequent constructions, however, were of an entirely different character, and the peculiarities embodied in her form and type were not developed further, although it was not possible then to foresee the speed that was attained some years later. Pending the realization of this dream, the evolution of the torpedo-boat lingered on listlessly until rather suddenly quickened in 1871. During the intervening years the field of competition had been transferred to the shores of Great Britain, and a rivalry had sprung up between two establishments on the Thames in the matter of fast steam launches. Greater and greater became the speed of the Yarrow and Thornycroft boats, until it apparently culminated in the Miranda, in which Mr. Thornycroft showed that the unprecedented rate of 16 knots an hour could be attained by a boat 50 feet long, displacing 3¾ tons. The observation of certain natural phenonema in connection with the performance of this boat helped to bring it into prominence, and as the Whitehead torpedo began to create a stir at about the same time, the attention of ordnance officers was attracted; torpedo warfare incontinently assumed a new phase; a new era was opened in naval operations. Since then human ingenuity and mechanical skill have been taxed to the utmost to perfect this weapon of offense, and develop the qualities necessary to overcome the obstacles and lessen the dangers presented by the equally progressive defense.

In 1873 the Norwegian Government received from Messrs. Thornycroft & Co. the first special fast torpedo-boat ever built. It was 57 feet long, 7½ feet broad, and displaced 7¼ tons on a mean draught of 3 feet. The hull, which was entirely of steel, was divided into six water-tight compartments, with three-sixteenth-inch steel over machinery and pilot-house, which was enough to deflect the Snider or Martini-Henry bullets; there were also movable steel shutters over the crew spaces forward and aft. Forced draft was supplied under the grate bars, and the motive power was applied by inverted direct-acting engines of 90 I. H. P., with surface condenser and independent pumps, and the propeller abaft the rudder. On the official trial the steam pressure averaged 85 pounds, vacuum, 25½ inches; the maximum speed was 14.97 knots—a knot more than was stipulated. This was due to a superior form of propeller designed by Mr. Thornycroft after several experiments carried on to determine the best model. The armament consisted of a towing torpedo 13 feet long, 9 inches in diameter, towed from the top of the smoke-stack. At a speed of 11 knots it diverged 40 degrees. The behavior of this boat at sea was said to be good by her commander, though her movements during a gale were remarkably quick. The structural strength was afterwards unintentionally tested by running with moderate speed on a smooth rock, off which she came afterwards without injury.

Two more boats were quickly ordered from the same firm for Sweden and Denmark. They were similar to the Norwegian, except that the air, feed, and circulating pumps were driven off the main engine, which had not been done before, as it was not thought possible to run them at such high speed. The Swedish boat made 15, and the other

15⅝ knots. The latter was fitted to use towing torpedoes from an upright pole 8 feet high, 6 feet from aft; it was found that the speed while towing was reduced to 10 knots, a very serious matter.

Messrs. Yarrow & Co. soon entered into competition in this new industry. Their first torpedo-boat was built in 1874 for the Argentine Government; it was 55 feet long, 7 feet broad, and on trial made 14 knots, the engines indicating 65 H. P. The armament consisted of one of Captain McEvoy's spar-torpedoes.

The Yarrow build differs from that of Thornycroft mainly in having an extremely arched deck, which, with the rounded bottom, gives the boat a nearly tubular cross-section, with the natural strength inherent to that shape. On the other hand, the head room inside is less than with the flatter deck.

The next size of boat produced was by Thornycroft in execution of orders for two boats for the Austrian and French Governments. Their length was 67 feet; beam, 8 feet 6 inches; draught, 4 feet 3 inches. The guaranteed speed was 15 knots for one hour for the Austrian and 18 knots for two hours for the French; on trial the former actually ran 18.202 knots in one hour, and the latter 36.05 in two hours. In these boats the crew spaces were permanently decked over with steel. A further improvement was also effected in supplying air at a pressure in a closed fire-room instead of blowing under the grate bars; this arrangement not only improved the mechanical results, but materially lowered the temperature of the fire-room, and made it much more habitable. For armament these boats were each fitted with two torpedo-spars 43 feet long, 4½ inches in diameter, arranged to rig out ahead or on the beam. The torpedoes were fired automatically or by electricity.

On reaching Cherbourg the French boat was altered to use the spar only ahead, one steel pole being used, 40 feet long, capable of depressing the torpedo 8½ feet below the surface. This was done in consequence of its having been shown that only 90 per cent. of the weight of explosive fired ahead could be safely fired astern, and only 35 per cent. on the side.

Early in 1877 experiments were also carried on in Cherbourg to determine the danger to the boat from the column of water. The Bayonnaise, an old wooden frigate, while in tow of a steamer, was attacked by a boat which approached with a speed of 14 knots, slowed down and stopped before contact, and successfully placed and fired the torpedo; a large wave was formed which drove the boat back, washing completely over her at the same time in a way that would have inevitably swamped an open boat. This emphasized the result of the fatal experiences during the American civil war, but showed that the cure had been found. It now only remained to protect the machinery and crew from small-arm or the rapidly developing machine-gun fire.

During this same set of experiments, one of the attacking boats failing to slow down sufficiently, and striking with a speed of about 8 knots, was somewhat doubled up about the bows. In view of the difficulty thus illustrated of manœuvreing with such nicety at the critical moment of attack, the French fitted their boats with a hydraulic buffer forward, supplemented by a sort of elastic steel whisker on either side to fend her off when striking a glancing blow. This arrangement was put to a crucial test not very long afterwards by one of their boats accidentally ramming a granite wall with a speed of about 14 knots; the foot of the buffer, which was of malleable cast iron, gave way, and the bows were crushed in and the forward compartment filled; but it was thought that the concussion was somewhat deadened in spite of the partial failure of the apparatus, and a favorable report was made on it.

A third size of boat was built by Thornycroft in 1877 for the Dutch and Italian Governments. These were 76 feet by 10, and made 18 knots with 250 I. H. P. They were similar in general design to their predecessors, except that a little more freeboard was given them forward. The one for Holland was fitted with outriggers for the spar-torpedo, but the Italian received a launching apparatus for the Whitehead.

The Lightning, built for the British Admiralty in the same year by the same firm, gave its name to a type, and was very far ahead of anything produced up to that time. It was 87½ feet long, 10 feet 10 inches beam, drew 5 feet, and, on trial with the original propeller, made 18½ knots over the measured mile. The hull was somewhat heavier than in her predecessors, and the lines fuller, with a view to better behavior at sea in rough weather, such service being anticipated. Steering gear was fitted for use on deck or in the conning tower, and the usual means of communication with the engine-room were provided. The top of the conning tower was so arranged that it could be raised or lowered so as to adjust the sight-space according to the range required or the protection necessary. The armament consisted of Whitehead torpedoes, there being one air-impulse discharging-tube forward which could be trained 135° on each side. Three torpedoes were carried, one in the gun and two on trucks just abaft it. A defect of this arrangement was in their exposure and liability to be disabled or exploded by the enemy's fire; it also necessitated retiring out of action after discharging one torpedo to load a second without exposing the crew. In boats for other countries tubes were built in the bows under cover, there being usually two openings near the cut-water, pointing directly ahead. A number of experiments were carried on later to determine the relative merits of several screw models, and the most efficient seems to have been one of Mr. Thornycroft's peculiar guide-blade propellers, with which, in 1881, a speed of 19 knots was attained by the Lightning with 423 revolutions and a displacement of 34 tons.

In 1877 Thornycroft also produced the 87-foot type of boat for France, six of them being ordered by that Government. They had 10½ feet beam, and the plan was adopted of galvanizing the under-water plates and frames, which practice soon became general. A spark-catching apparatus was fitted at the base of the smoke-stack. Thornycroft also brought the propeller forward of the rudder now, while Yarrow kept it abaft in many of his boats. With the screw in the normal position the manœuvreing power was found to be much improved. Moreover, when the rudder is forward of the screw, the void occasioned on the after side by putting the helm hard over was apt to make the screw race badly. Later on the shaft was inclined to the water line, so as to bring it out aft just above the bottom of the keel; in this way half the area of revolution was below the boat, a good supply of water being thus obtained for it, besides the ability to carry a larger propeller. In some boats the rudder is hung from the stern above water, but in others a rudder-post is provided, connecting with a skeg-shoe, which protects the propeller from underneath; in some cases support is provided by the propeller hub.

A great increase in turning power was obtained by Yarrow & Co., by the introduction, in 1878, of a forward rudder, which could be lowered in place or raised in a well about 10 feet from the bow; it was so arranged as to be dropped in case of being fouled, and could be worked either independently or in conjunction with the after rudder.

In experiments instituted by the British Admiralty in 1879 it was found that under the action of both rudders the turning circles were reduced to about one-half of that when actuated by the after one alone. In going astern also the boat was under complete control.

Thornycroft in turn supplemented this increased rudder power by the introduction, in 1878, of a steam-steering engine, which made its way in the face of much adverse criticism. To those who deemed such small engines superfluous, it was argued that to bring about the most perfect handling it is necessary for the officer himself to steer, and it is highly desirable to relieve him of everything approaching physical exertion when all his faculties are absorbed in seeking out the enemy, approaching him in the most advantageous way, and discharging the torpedo at the right second. They held their own, and few torpedo-boats to-day are built without.

The race by this time was no longer confined to the two celebrated English builders, as firms had sprung into prominence in several of the continental countries. In 1878 ten boats ordered by Russia from the establishment of F. Schichau, at Elbing, Prussia, made over 17 knots for two hours in moderate weather, on a length of 66 feet and 11 feet 3 inches beam; later, in smooth weather, they reached nearly 18. The premiums paid on these boats for excess of speed and other qualities amounted to 20 per cent. of the contract price. These German boats were rather higher out of water than the English, and are said to have behaved remarkably well on the voyage to St. Petersburg.

The contest being fairly begun in speed, size, and offensive power, and marked by a steady increase in each quality, torpedo-boats gradually came to be divided into first and second classes; the former including those of a size to keep the sea and act independently, while the second class were of a size to be carried by ships and used as auxiliaries to them. The desirability of having them thus classified, so as to adapt their service to their most prominent features, was soon recognized by all nations. In 1879 the early ones built by Thornycroft for the Scandinavian countries were sent back to him to have the sterns altered so as to put the propeller forward of the rudder, and to have other minor changes made to adapt them to the circumstances and uses of second-class boats.

The first type ordered by the British Admiralty specially for service as second-class boats were 60½ feet long, and were fitted with hinged side frames or cradles, invented by Mr. Thornycroft for discharging Whitehead torpedoes. The arrangement did not prove successful, as, there being no means of ejection, they had to propel themselves out of the cage, which necessitated slowing down to about 3 knots. Side suspension fittings were also devised in France, Austria, Germany, and by Mr. Whitehead himself, some for discharge in fore-and-aft, and others in thwartship direction; although successful to a certain extent they were gradually given up, and there being no room in second-class boats for air-compressing machinery, Mr. Yarrow, in 1880, devised a steam-impulse gear, which was tried in a launch and generally adopted.

Internal improvements in mechanical detail were rapidly developed at the same time that the size of the boats increased. In 1878, in a boat for the Spanish navy, Yarrow did away with smoke-stacks, providing in their stead two ports, one on each side, through both or either one of which the products of combustion could be directed. In the following year they reverted to the use of funnels, but fitted them with elbow joints, so that when preparing for attack they could be turned down and directed overboard, thus decreasing the visible size and concealing possible sparks or flames. This system has since been given up.

In 1878, also, supplementary engines came into favor for the fans and circulating and feed pumps, so that with the engines stopped or in motion powerful means would be at hand for freeing the boat of water; also, in case of sudden stoppage, valves were fitted for admitting steam from the boiler direct to the condenser or to the outer air, so as to permit the firing to be kept up and sudden changes of temperature in the furnace prevented.

Thornycroft and Yarrow both provided means for keeping steam out of the fire-room in case of tubes or sheets giving way. The method adopted by the former was simply to hang a system of light steel flaps at the door of the ash-pit, which are held open by the passage of the forced draft, but would close automatically under a greater back pressure, thus directing the steam through the uptake and smoke-stack. To prevent overpressure in the furnace a connection is made by a pipe from the ash-pit to the deck, closed by a spring valve, which lifts under high pressure. Yarrow's arrangement was similar in principle, but he had the ash-pits open at the back end of the boiler; an air-tight bulkhead, extending from the face of the boiler to the side of the boat and deck above, separated the boiler-room from the fire-room, and light metal flaps were provided in this bulkhead to act like those of Thornycroft at the ash-pit doors. This method provides for the case of a shot entering the sides or back of the boiler, it being thought that there would be great condensation on the sides and bottom of the boat cooled by the external water; but it leaves a large waste-space outboard of the boiler, which in the Thornycroft boat is utilized in the stowage of several tons of coal, which, in turn, afford protection to the boiler besides increasing the sea endurance. In Yarrow's later boats most of this space has been retained for coal stowage. These apparatus were unintentionally tested in one of each maker's boats; a tube gave way entirely, but no steam reached the fire-room, though in one case the fires had to be hauled. Pipes were also fitted afterwards leading from the sea to the top of the furnace, so the fire could be put out at once in case of accident.

In 1879 the British Admiralty issued invitations to the principal builders to construct trial torpedo-boats, with the object of finding out what kind would be built by the different firms and what rate of delivery could be depended on. In response Yarrow & Co. furnished one 86 feet long, 11 feet beam, with which they obtained a speed of 21.93 knots; the armament was, as usual, three Whitehead torpedoes and one air-impulse tube forward, capable of train in any direction.

In the same year the Admiralty bought a boat from the Herreshoff Manufacturing Company, of Bristol, R. I., and some trials were instituted in December of that year between it and a Thornycroft. The American boat was 59½ feet long, with 7½ feet beam; the build was composite under water, with a steel skin above; displacement, 8 tons. Besides the novel features of the coil-boiler and keel-condenser there were several new departures in this boat, prominent among them being the position of the screw, which was underneath the boat at about one-third of her length from aft, the shaft coming up through the bottom of the boat at an angle. In order to make the propeller revolve in a more nearly vertical plane, the bold plan had been adopted of springing the steel shaft throughout its length; it ran through a brass tube, which was bent to the desired curve, making a continuous journal. In practice this was found not to heat too much, probably owing to the radiation in the passing water. The rudder also protruded below the line of keel, and was free to revolve in any direction, so that it was more easily controlled in backing, the preponderating side then being thrown forward. The speed attained by this boat was 16 knots on trial, and the manœuvreing power very great.

Experiments carried on by Yarrow showed that in point of speed (in smooth water) this position of the screw was not the best, the speed increasing for the same H. P. as the screw was moved aft. In rough weather some advantage would probably be found in the screw working in solid water. In one of the boats built for the Chilian navy Yarrow put the propeller in this position.

The Thornycroft boat selected to compete with the Herreshoff was 63 feet over all, displacing about 10½ tons, and was fitted with a new and, as it proved, highly successful device for raising steam quickly. High-pressure steam from the ship's boilers was led by a flexible pipe to the boat's fan engine, setting that in motion, and also through an injector in the bottom of the boat's boiler to the water in the latter, heating it quickly. The excellent results obtained led to the general adoption or this attachment by the Admiralty.

Starting with cold water, the Herreshoff got away in eight minutes two seconds with 90 pounds steam, and the Admiralty boat in nine minutes thirty-five seconds. The latter being the faster boat, however, reached the end of the course two minutes nine seconds ahead of the other in a run of twenty-four minutes thirty seconds, counting from the time of starting fires.

This decided the matter in favor of the English boat. In a subsequent order for twenty boats, however, the Herreshoff boiler was stipulated for in the specifications of two of them, probably for more exhaustive experiments. Both France and England also bought some smaller, vedette, boats, 48 feet long, from that firm, which produced quite remarkable results, a horse-power being developed for every 41.42 pounds of machinery, including the water in the boiler and in the tank; they also rode the seas with conspicuous facility.

The first 100-foot boat was built by Yarrow in 1879 for the Japanese Government, and in 1880 the Batoum steamed from that company's yard to Nikolaieff. This boat was also 100 feet long, beam 12½ feet, draught aft 4 feet, displacement 48 tons. The forward part is protected by a turtle-back, terminating at its after end with the conning tower. On trial, flying light, a mean speed was obtained of 22.16 knots for six runs over the measured mile. The screw was about a foot abaft the after rudder. The bunker capacity was only enough for 350 miles at 10 knots, but enough could be carried for 1,000 miles. The armament consisted of two torpedo-tubes, built in forward under the turtle-back, and four Whitehead torpedoes. During the voyage to the Black Sea many defects were recognized, most of which were remedied in that and subsequent boats.

In the same year Thornycroft obtained, on a length of 90½ feet, a mean speed of 21.75 knots for six 1-mile runs.

The rapidity with which orders for these boats could be filled was illustrated in the case of a flotilla ordered from Yarrow for the Grecian navy in 1880. The contract was to build, with all possible speed, six 100-foot, sea-going torpedo-boats. The keel of the first one was stretched on December 15, and the official trial took place February 23; all six were delivered within four and one-half months.

In consequence of injury to boats' bows in several instances of collision, it was found necessary to strengthen them forward, and they came to be built with strong ram bows to increase their offensive power, which has remained the general practice since. The experiment was also tried in England of building one of brass, in view of the extremely light scantling on which it was necessary to construct them, and the consequent importance of preserving them from corrosion. It does not seem to have been thought necessary, however, to continue in the use of this expensive metal, as good zincking, coupled with assiduous care and the use of protective zinc slabs afterwards, gave promise of preserving even the one-sixteenth-inch plates used for some parts of the skin.

In 1881 Yarrow had raised the speed to 22.46 knots over the measured mile in a 100-foot boat for the Italian Government. Although high speed was required the beam was kept at 12½ feet, it having been found by experiments that less than that would not secure the range of stability necessary to make these boats safe in rough weather. There were two ejecting tubes built in forward, snugly housed under the spacious turtle-back, which had become a prominent feature of the Yarrow boats. The propeller was two-bladed, and the engines during the trial made 480 revolutions, which showed a piston speed of 1,280 feet a minute; this was the more remarkable from the fact that with the locomotive boiler no oil can be admitted to the interior of the engines on account of the priming set up by any of it finding its way in through the condenser and feed pumps.

This boat was also the first to be fitted with the patent arrangement for preventing the fires being extinguished by water rising in the fire-room. The device consists simply of continuing the ash-pans up around the sides of the furnace to above the level of the sea outside, and securing them water-tight to the shell of the boiler, the fire-door being also practically water-tight. The steaming power of the boat, therefore, will continue as long as the fire lasts, even though the fire-room be completely flooded. The amount of fuel usually on the bars when running at full speed will carry these boats 40 to 50 miles at the rate of 10 knots after the firing is stopped. The pumping power is also maintained, of course, as long as steam is generated.

In this connection may be mentioned a system of steam ejectors that had been devised, whose capacity became so enormous that together with the various pumps they could free a boat in seven and three-fourths minutes of a weight of water equal to her displacement. Their presence, of course, admitted of a decrease in the pumping power, and as it had been found necessary to have an extra oiler to attend the independent pumps, the practice was resumed by many of running them off the main engines; in Schichau's boats the speed is reduced to one-third, the connection being by means of an endless screw in one with the main-shaft gearing into a worm-wheel on the shaft that runs the pumps.

One of the most formidable boats built at this period was a Thornycroft ordered for Denmark; with a length of 110 feet, 12 feet beam, 6 feet 3 inches draught, and 52½ tons displacement, an average speed of 19.91 knots was maintained for three consecutive hours. With a coal supply of 10 tons she could steam 1,200 miles at the rate of 10 knots. Two launching-tubes were built in forward for 19-foot Whiteheads, carrying 80 pounds of gun-cotton. Four of these torpedoes were carried, and a Hotchkiss machine gun. In a sister boat the Danes reverted to the straight stem, as it had been noticed that the water raised by the swell of the ram-bow had entered the torpedo-tubes and reduced the speed.

This defect of the ram-bow was remedied in the following year in a type represented by four boats built by Yarrow for Brazil. The torpedo-tubes, instead of opening out like hawse-holes forward, were completely inclosed within the hull, and fitted with smooth hawse-bucklers that followed the shape of the bow-plating; this also decreased the shock of striking a head sea. The boats were 110 feet long and 12½ feet broad, displaced 52 tons, and made 20.3 knots for three hours. At moderate speed they can make 1,200 miles on their own coal. For the passage to Brazil they were fitted with temporary masts and a 15-inch false keel.

A French boat built by J. A. Normand, Havre, gave excellent results in the summer of 1882. The dimensions were—length, 108 feet 2 inches; beam, 18 feet 10 inches; at the speed trials the boat was complete, with launching-tubes and impulse-gear, two boats, six 19-foot Whitehead torpedoes, &c., but carried only coal enough for the run; on a displacement of 43 tons an average of 20.62 knots was maintained for three consecutive hours, the coal consumption being 2.37 pounds per I. H. P. per hour. In the opinion of Mr. Normand this extremely low rate of consumption was "not exclusively due to the boilers."

Yarrow's second-class boats deserve special mention, one built for the Admiralty having maintained an average speed of 17.27 knots for two hours on a length of 63 feet. The trial was in February, 1883, under the Admiralty conditions. The beam was 7 feet 9 inches, displacements 12½ tons. There were two troughs forward for Whitehead torpedoes, inclined downward at an angle of 6°; the impulse-gear was steam, arranged so that it could be started in the conning tower; the cylinders, being entirely covered by the deck, and being close to the boiler, were kept warm and ready for use.

A boat of the same dimensions built for the Brazilian iron-clad Riachuelo, tried under the same conditions in January, 1884, obtained a speed of 18.1 knots an hour.

The Soukhoum, built for Russia by Thornycroft in 1883, was one of the rapidly succeeding steps in the direction of larger size. She was one of four ordered from England, France, and Germany, 113 feet in length, 12½ feet beam, 6 feet draught, 60 tons displacement, built of galvanized Bessemer steel, in eleven compartments separated by eight whole and two half bulkheads. Many improvements were carried out suggested by Lieutenant Sazaremi, who had taken the Batoum to Nikolaieff. A mean speed of 18.96 knots was maintained for three hours, and a mean of 19½ for six runs over the measured mile. The coal supply is sufficient for 1,000 miles at 11 knots, but, like the Batoum, the regular supply of fresh water was only enough for about 50 miles. For long voyages she spreads 1,000 square feet of canvas on three sliding-gunter masts, which can be unshipped and left ashore. Two torpedo-tubes, with four Whitehead torpedoes and two single-barrel 37-millimeter Hotchkiss guns, constitute the armament, and an electric search-light was provided.

Good boats were also being turned out in Italy now, the Rigel, built by Orlando Brothers, Leghorn, 100 feet long, 35 tons displacement, making an average of 21.4 knots at the trials.

In Germany, one of Schichau's boats made 21.7 knots over the measured mile, and in five hours and twenty-six minutes, carrying a load of 12½ tons, ran 115 knots, or 21⅙ knots per hour.

A prominent ocean passage was that of the Childers, sister boat to the Soukhoum, which left London for Australia, in December, 1884, and made the voyage without injury.

The performance of all these boats, coupled with more recent and probably severer trials of their behavior in various evolutionary squadrons and coastwise trips, show that they are sea-worthy in the sense of being able to survive heavy weather; but even though they should suffer no grave injury, they are balloted about with such great liveliness in even moderate weather that their offensive power is practically destroyed for the time being, and life on board has been found so trying that the crew would evidently soon become exhausted for want of rest and food. It is also necessary to stop every few days to sweep the boiler tubes and clean out the condenser. Their strength of hull and the efficiency of their water-tight subdivision had been well tested in 1882, in Spezia, where two Yarrow boats reached port after a collision, in which the ram of one entered the bow of the other and protruded beyond the farther side. But rough usage tells very quickly upon these delicate organisms, and the lesson has had to be learned that while torpedo-boats may be invaluable for the purposes that led to their creation, their sphere cannot, with impunity, be expanded to include every kind of service afloat.

Another important element of non-habitability has been found in the high temperature to which the interior of these boats is inevitably raised by the sun striking on the unprotected metal skin. To remedy this inconvenience, which might easily become serious, will require additional weight (and consequently a still greater increase of displacement), whether the end be accomplished by external wood sheathing, or by a ventilated air-space inside, as has has been suggested by Mr. Normand, the eminent French builder.

For sea-going, independent craft a length of 110 feet is evidently not enough, if it be intended to keep them at sea longer than one or two days at a time; and a perception of this has led to a rapid growth in size, speed, and offensive power of first-class boats. The second class had attained wonderful results for their size, making 18.1 knots, standing perfectly the strain of being hung from the tackles, and having the offensive power of two Whitehead torpedoes; but being limited in size by the ability of ships to hoist and carry them, and being ill-adapted to the requirements of general service, they have been falling more or less into disfavor, and have in some countries been relegated to coast defense. To replace them a type of steam launch was designed by Yarrow & Co., equally well adapted for picket duty, torpedo work, or general service; they were 54 feet long with 9 feet beam and about 10½ tons displacement; the engines indicate 150 H. P., and drive them 15 knots. They are built of steel with open stern-sheets, and a launching-tube forward which can be unshipped and replaced by a gun or freight. A smaller size has also been found serviceable, prominent among which may be mentioned the 39-foot Herreshoff of 7¼ tons displacement. This launch is of wood, with triple expansion engines, and on trial made 12.78 knots going ahead and 8.9 going astern; the dead wood being cut away aft, the diameter of her turning circle is between 60 and 65 feet. From full speed ahead she was brought to a state of rest in 40 feet. White's "turn-about" boats also proved highly successful.

The three recent wars have proved rather barren as regards influence on the type or even details of torpedo-boats, the inferences drawn and the discussions that have arisen bearing rather more on the kind of torpedo than the style of boat. On the Danube and at Sheipoo open launches successfully exploded spar-torpedoes alongside the enemy without being themselves sunk, which was in marked contrast with the experiences of the American civil war and subsequent experiments by various nations. Their immunity may have been due to incidental circumstances, such as obliquity of impact, &c., but their escape was so close as not to reverse the dictum that protection from the wave or water column should be afforded.

One fact demonstrated on the Danube in an intensely practical way and corroborated by experiment afterwards, was that a fast boat, if kept at speed, has much less to fear from the effect of shot-holes through the bottom than had been thought, the progress through the water greatly reducing the speed of inflow. In the experiment mentioned a Martini-Henry rifle bullet was fired through the bottom a foot under water, making a hole a little over three-fourths of an inch in diameter; with the boat at rest the water entered fast enough to fill a bucket in twenty-five seconds; when she was making about 10 knots, practically none entered. This was apparently due to the disturbed condition of the adjacent water arising from the friction of the skin. The same would undoubtedly obtain with a larger hole, though perhaps to a less extent. This remarkable source of safety, coupled with efficient internal subdivision and with the enormous ejecting power now provided, and with the ability to run (as well as pump) for 40 or 50 miles with the fire-room flooded, shows that the sinking of the boats is perhaps the least danger to be apprehended. Protection for the machinery and for the *personnel* is most important, in the order given; if only the presence of the officer can be assured at the steering-wheel and firing-keys until the blow has been delivered, the destruction of the rest of the *personnel* could hardly be so rapid and entire as to paralyze the attack; and even if it were complete the attack might possibly yet be made and retreat accomplished. But one shot in the one boiler or among the machinery renders the attack abortive, and insures the total loss of the boat or its capture by the enemy.

In Callao, 1879, it was simply shown that one spar-torpedo does not afford enough offensive power to make the attack effective, even when the defense consists of a simple cordon of booms.

The terribly destructive power of this arm, when unopposed by modern weapons or by ordinary precautions on the part of the defense, was accentuated on the river Min and at Sheipoo, and the success of the French boats in these attacks led to clamorous advocacy of the spar-torpedo by many writers. While many of the circumstances would tend to lessen the force of the arguments advanced, the bare facts had the, perhaps, wholesome effect of tempering the apparently absolute sway of the fish torpedo. The first navy to show tangible signs of having drawn tactical conclusions from these actions was that of Turkey, which lately had a boat built in France to use the spar as well as the Whitehead torpedo. Other nations have followed this lead, and it seems possible that this composite armament may come in general favor. This change has its influence on the build of the boat; to merely add the spar and fittings to a boat not designed to use them would not be the best policy, for not only has all that extra weight to be carried, but it is crowded at an extreme end of the boat, where the lines are finest, and she would be proportionately thrown out of trim.

In 1884 the British Admiralty decided to give all first-class boats a tube in the stern as well as two forward, and some were delivered armed in that way; but this was reversed in 1885.

The locomotive boiler has survived in England and continental Europe, its efficiency and economy having been remarkably increased by improvements in various details brought by different builders, mainly British, German, and French; these improvements have also permitted an increase of size, until a single boiler suffices to furnish steam at 140 pounds pressure, sufficient to develop 1,500 I. H. P. The excessive liability of this type of boiler to foam has been counteracted by allowing no lubricant into the interior of the engines, even for a piston speed of 1,300 feet; the terrible effect of a shot or rupture liberating such a volume of high-pressure steam has been reduced very greatly in the manner described previously. Schichau has also patented a bottom draft, which does away with the necessity of a closed fire-room, and is applied to the boilers of all his boats. The front of the boiler alone is inclosed, the pipe from the fan leading to this space, and when the furnace door, which is air-tight, is opened the blowing engine is cut off. The triple expansion type of engine, also, which owes much of its development in torpedo-boats to German works, has notably increased the economy in the application of power; last summer one of Schichau's first-class boats made 1,000 miles at 10 knots on 4.6 tons of coal. The endurance naturally varies according to the exigencies of the required service, it being possible in some cases to reduce the weight of coal carried to add it to the engines and boilers.

Arming torpedo-boats with machine guns has become a necessity of late to enable them to attack similar boats and resist attack by them; and, in the large ones, electric search-lights are being fitted in the face of much criticism. While it is undoubtedly true that this light would rob a boat of the invisibility that forms an essential feature of the offense, it is also to be observed that it need not be used under such circumstances, and that at other times, as when acting on the defensive or hunting for the enemy's boats, it might be of great value.

For ejecting Whitehead torpedoes from the tubes, slow-burning powder is being used in many services in place of the air or steam impulse, though some authorities do not yet approve the system.

The boats now about to be described represent fairly the most recent productions of prominent builders.

The Falke, built by Messrs. Yarrow & Co. for the Austrian Government, is 135 feet long, with 14 feet beam, 5½ feet draught aft and 2¼ feet forward; 87 tons displacement. The skin is of galvanized steel plates one-eighth to one-fourth inch thick, the latter being only used on the ram bow and a few other parts where special strength is required. The deck has the arched form peculiar to the Yarrow build, and the conning tower for ordinary navigation is placed on top of it amidships, away from the spray and noise under the bow, there being as usual two smoke-stacks, and the view unimpeded forward. The fighting tower is forward. There are two rudders, one forward and one aft, both worked by hand or steam. The engine is three-cylinder, compound, surface-condensing, indicating 1,250 H. P., and the steam is furnished by one locomotive boiler having 44 square feet of grate and 2,000 square feet of heating surface. As in nearly all modern boats, the draft is forced by the air pressure maintained in a closed fire-room. The boilers and engines are protected by coal laterally and from forward, and the fire-room is so arranged that when it is flooded air can still reach the fires. At the trial in December, 1885, the average speed in six runs over the measured mile was 22.3 knots in fighting trim with smooth water; flying light, 24 knots was made. The coal supply is 28 tons, which is expected to carry her about 2,000 miles at a speed of 10 knots. For long passages she is fitted with two pole masts spreading five fore-and-aft sails. There are two machine guns. Only two launching tubes are fitted, discharging straight ahead, and the intention has been not to carry any spare torpedoes, but devote their weight to coal and motive power. This notable tribute to the desirability of speed and endurance reduces very greatly the offensive power and seems open to the charge of being excessive.

The Adler, sister boat to the Falke, recently launched by the same firm for the same country, made 22.4 knots on trial, loaded.

The armament of a vessel building for Italy seems more efficient than that just described. This one approaching completion at Yarrow's yard is 140 feet long; she will be propelled by twin screws, the estimated I. H. P. being 1,400. There will be two tubes forward for ejecting Whitehead torpedoes in a line parallel to the keel, and a few feet abaft the middle there is to be a turn-table, carrying two tubes diverging 6 degrees from each other, and capable of train in any direction. This was suggested by Mr. Yarrow with the idea that by firing both at once with that divergence there would be a better chance of hitting. He proposed the same feature for the bow tubes, but it does not as yet seem to have been adopted.

The French adhere to the bow tubes alone, but always provide space for two spare torpedoes abaft them; if this causes the tubes to project outboard much they give the boat a straight stem. The late boats ordered from various firms are 115 feet long, 11 broad, and draw 6½ feet loaded. The stipulated speed is 20 knots. The conning towers are so arranged that the officer standing abaft the helmsman will see over him, each having a separate line of sight-holes.

The Orion, recently built for the Spanish navy by the Germania Works, Kiel, is 124 feet long, 15 feet 8 inches broad. On trial it made 19.86 knots for five consecutive hours, and averaged 21.53 knots for four runs over the measured mile; at 10 knots it can steam 2,100 miles with full equipment. There are two tubes forward for Schwartzkopff torpedoes. One 37-millimeter Hotchkiss gun is placed on the starboard side forward, and one on the after pilot tower. In the forward tower is the gear for firing the torpedoes, and for steering by hand or steam, and in the after tower there is a hand-steering wheel. The motive power is furnished by one locomotive boiler, built entirely of German steel, except the copper fire-box and brass tubes. The engines are of the triple-expansion type, indicating 1,000 H. P. The weight of all machinery, including water and all auxiliary engines, steam steerer, donkey pump, &c., is less than 34 tons. There are eight water-tight compartments, in five of which there are ejectors of 40 tons an hour capacity each. A dynamo has been installed on board to feed a 6,000-candle search-light and twenty incandescent lamps.

Of Herr Schichau's recent productions the most prominent is one ordered last year for China, 164 feet long by 20 broad, 115 tons displacement, to make 23 knots; the triple-expansion engines to develop 1,500 I. H. P. The bunker capacity will be sufficient for 3,500 knots at 10 knots.

The type adopted in 1885 by the British Admiralty is 125 feet long, 13 feet beam, draught 6 feet 2 inches. The guaranteed speed was 19 knots, but this has been exceeded by those tried so far. One, built by Thornycroft, averaged 20.9 knots for six runs over the mile course. These boats are to steam 2,000 miles at 10 knots on their own coal. They have not the peculiar arched deck of the Yarrow build, nor the superstructure of the Thornycroft, but a clear deck. They are rather higher forward than their predecessors, sloping down toward the stern, and have a tapering tubular snout for the forward torpedo gun. There are two conning towers, with steam steering gear, also a search-light. The torpedoes are ejected from one tube forward in line with the keel, and two tubes at each tower, on turn tables, capable of train in any direction; the tubes of each pair are at an angle with each other, so that by pointing the forward turn-table right ahead, one tube would discharge off each bow; in the same way aft, one can be fired off each quarter. They also carry a machine-gun armament.

.The later boats have been fitted with White's double rudder aft (described further on), by which their manœuvreing qualities are greatly improved, the diameter of the turning circle being about three lengths. With the arrangement adopted, however, injury to one rudder would cripple both; the chain tiller-ropes also are exposed on deck.

A boat for Turkey, lately built by the Société des Forges et Chantiers, La Seyne, deserves special attention because of being the first provided with attachments for spar-torpedoes as well as two tubes for Whiteheads forward. A steel spar carries the torpedo at 23 feet ahead and 8 feet under water. The boat is 101 feet 8 inches long, 11 feet 8 inches beam, 5 feet 8 inches draught, 43 tons displacement. The average speed during four runs over the measured mile was 20.3 knots, the power being furnished by one locomotive boiler of 550 H. P. The hull is divided into seven water-tight compartments. From the conning tower the Whiteheads can be discharged and the spar-torpedoes fired. The armament includes two Nordenfeldt guns.

Among American builders the type of torpedo-boat has a representative in the Herreshoffs' Stiletto, although it has not been armed. This craft has wood frames and skin with iron diagonal braces, knees, and bulkheads; her length is 94 feet, beam 11 feet, draught 4½ feet. The typical Herreshoff coil boiler, in a closed fire-room with forced draft, furnishes steam for a two-cylinder inverted compound engine, which, with the maximum pressure of 150 pounds, makes 480 revolutions, indicating about 450 H. P.; for ordinary speeds natural draft can be used. The essential feature of the engine is in the construction of the cylinder, which is inclosed within another, an annular valve working in the space between; the ports being arranged all round the inner cylinder at top and bottom, the steam pressure is delivered on the piston from all sides of the cylinder at once. The shaft comes out at the lower end of the stern-post. The Stiletto has run 7 miles at the rate of 21.7 knots, 30 miles at 20.4 knots, and is expected to maintain 19½ knots for three hours. The total weight of machinery and water is only 10 tons, or about 50 pounds for each I. H. P.; the extra weight carried in deck-house, passengers, spars, &c., was 10,000 pounds. The bunker capacity is 6 tons, on which she is expected to run 800 miles at the rate of 9 knots; stowage for three times that amount of coal in bags is easily effected.

The Herreshoffs have built several launches for Peru fitted with torpedo-spars. They consider a composite build the best up to a length of 100 feet; above that they advocate the use of steel, of which metal they are prepared to build boats up to 150 feet in length.

Yarrow has been recently engaged on a boat for Japan, 166 feet long, and of 180 tons displacement, to be propelled by twin screws, and the machinery to be protected by 1-inch steel armor. Guaranteed speed, 19 knots. The armament will consist of gear for discharging four Whitehead torpedoes, and of several machine guns.

With the increase in size of torpedo-boats has arisen the question of manœuvreing power, and the subject of twin screws has been revived in competition with other means of attaining the end. In view of the importance of this quality, great interest attached to a trial in England, in November 1885, of a boat designed and built by Mr. J. S. White, of East Cowes, on his "turn-about" system, the conception of which was partly due to the Herreshoff boat tried in England in 1879. The principal features of this build are the cutting away the dead wood and having two rudders, one in the normal position and one (balanced) just forward of the propeller above the shaft. The boat tried was 150 feet in length, 17 feet 6 inches beam, 125 tons displacement, built as usual of thin steel. Steam was furnished by two locomotive boilers separated by a fore-and-aft water-tight bulkhead, the connections being made so that either can be used independently. The engines are three-cylinder compound, and developed 1,387 H. P. with a mean boiler pressure of 126 pounds, and 319 revolutions. In fighting trim she made 20.79 knots for six one-mile runs, and turned as follows: At full speed, helm hard over, starboard circle in one minute and seventeen seconds, port circle in one minute twelve seconds. The diameter of the circle described was about one and one-half lengths, a notable improvement over that of previous boats of the usual type, which had taken about seven lengths to turn. The times, of course, were not proportionately decreased. It was found that the removal of the dead wood reduced the heel considerably in turning.

This boat, called the Swift, which had been constructed and tried by the designer at his own risk and expense, but with a view to purchase by the Government if successful, has been acquired by the Admiralty for service as a torpedo-boat catcher.

This new name indicates a new type of vessel which has been gradually evolved from the torpedo-boat. As the danger to battle-ships from these small craft has become more and more obvious, there have come to be built, on the principle of setting a thief to catch a thief, larger boats of similar characteristics to hunt the smaller ones. "*A torpilleur, torpilleur et demi.*"

These torpedo hunters are a connecting link, as it were, between the boats upon which they are intended to prey, and larger vessels, fitted to use submarine projectiles as a principal weapon, which have been the subject of much study, and which have achieved remarkable results. A retrospect would lead back to 1872 when the Alarm and Intrepid were laid down by the United States Navy Department. These were armored torpedo-rams, which seemed to be the direction in which American thought continued to tend until checked by the brusque appearance in Europe of the fast boats already discussed.

The Alarm, designed in 1871 and launched in 1874, is 173 feet long, 28 feet broad, and drew 11 feet aft, with a displacement of 720 tons; the hull is of iron, with cellular bottom, and additional subdivision by water-tight bulkheads, valves being fitted to fill the double bottom when desired to increase the immersion. The bow, which terminates in an enormous under-water snout, is protected by 4 inches of iron armor tapering aft; the rest of the hull is unprotected, excepting that under the wooden deck is one of ⅜-inch steel; the pilot-house, situated well aft, was made musket-proof. The battery consists of one 15-inch smooth-bore forward, firing directly ahead, the training being effected with the helm; owing to the buoyancy of the ram-bow there were 25 tons of ballast put in forward, which weight could be utilized to great advantage in improved armor or a heavier modern gun. There were also four Gatlings carried on the rail. The torpedo armament consists of three gun-metal under-water torpedo-spars, one projecting from the end of the ram to a distance of 30 feet, and the other two rigging out 17 feet on the broadside; the torpedoes are fired by electricity. The motive power is furnished by four cylindrical boilers, and applied through direct-acting compound engines indicating 800 H. P., with anthracite coal; with Cumberland coal it has been estimated that 1,000 horse-power would be developed. The first propeller fitted was a Fowler wheel; this, proving unsatisfactory, was replaced some years later by the Mallory steering propeller, which involved deepening the keel aft and increasing the draught to 14 feet to secure the necessary diameter. The maximum speed attained with it and with anthracite coal was 11.42 knots. No sail power was provided. As indicated by the mode of installing the gun, the Alarm was intended to fight bows on, great manœuvreing power being aimed at for that purpose.

The Intrepid, of 800 tons, built at the same time as the Alarm, represented similar ideas, but was given no battery, and was slower and less successful. She was recently cut down with a view to being rebuilt for other service. Her length was 170 feet, beam 35, draught 12 feet of water. The material of the hull was iron, and the water-line was protected by a belt made up of 5 inches of laminated plating and 11 inches of wood backing, which extended to the upper deck beams; the lower part of the smoke-stack was also protected by 9 inches of similar armor, and the deck was made up of two ¾-inch thicknesses of plate covered by the usual deck planks. The pilot-house was musket-proof. The armament consisted of five torpedo-spars, one rigging out ahead from the end of the spur, and the others on the broadside. She was propelled by twin screws, driven by direct-acting compound engines of 643 collective I. H. P.; maximum speed 10.6 knots.

Inasmuch as the project represented in their design was subsequently carried out in such entirely different lines, owing to the then rapidly changing conditions of naval warfare, these two vessels may perhaps be refused a place in the history of the development of torpedo-vessels as now understood; but when first designed they were pioneers in the field, giving way, as demanded by the laws of progress, to the very different class called forth by the new elements suddenly introduced. Armor had to be eschewed and speed attained at all costs; but above all it is the automatic fish torpedo or the submarine projectile that makes the torpedo-vessel an actual practical fact.

In this connection should perhaps be mentioned the Destroyer, designed by Captain Ericsson of Monitor fame. A discussion of her qualities would hardly be in place in this paper, however, as it is the submarine gun and projectile torpedo with which she is armed that has made her reputation, and not the type nor any features of her design. As claimed by her owners, " any craft of suitable form and sufficient draught of water for the due immersion of the submarine gun will answer equally well as regards the operation of the torpedo machinery."

Tentative efforts were made in different quarters to produce an effective ship, but the first of what may be termed the modern type of torpedo cruiser was the Ziethen, of 975 tons displacement, built for the German navy in 1876 by the Thames Iron Works Company, London. She is 196 feet 10 inches between perpendiculars, 26 feet 10 inches beam, with 11½ feet draught; twin screws; maximum speed 16 knots. Her armament was one launching-tube for Whitehead torpedoes forward, and one aft, both 6 feet under water, beside one 4¾-inch, and four 3½-inch B. L. R., and four Hotchkiss machine guns.

This lead was quickly followed by the various maritime nations with greater or less success, in many instances the speed being much lower than hoped for and the vessels in consequence considered more or less failures. These new large vessels combining to a greater or less degree the lightness of hull and of gun armament of the torpedo-boat, with the sea-worthiness and enlarged sphere of the cruiser, the one or the other being the more accentuated according to circumstances, have been variously designated as torpedo cruisers, torpedo gun vessels, torpedo dispatch boats, torpedo rams, &c., according to the service for which they are designed.

As craft of an intermediate size appeared in the shape of torpedo-catchers, the term "boat" began to seem indefinite and inapplicable; in the absence of any natural positive dividing line, a displacement of 300 tons has been adopted in the Office of Naval Intelligence as the limit between "boats" and "vessels."

The Polyphemus, laid down in September, 1878, hardly comes properly under the head of torpedo-vessels, although fitted with five discharging-tubes. Designed for a ram, fitted with deflective armor, and intended to carry no battery, she excited considerable comment, and her recent performances at Berehaven seem to have placed her in a favorable light as a ram; but that very fact, coupled with her displacement of 2,640 tons, tends to take her out of the category of torpedo-vessels. Without pausing to examine several other well-known ships, on the plea of their being deficient in speed or other qualities, and, consequently, not taking part in the development of the torpedo-vessels of to-day, we come to the first prominent vessels of this enlarged type in the Blitz and Pfeil, of the German navy. They were designed in 1879, launched in 1882, are 245 feet long, 32½ feet beam, and displace 1,380 tons on 13 feet 6 inches draught. They were built of steel on the longitudinal frame system with seven thwartship bulkheads, five reaching to the upper deck; a double bottom extends under the engine and boiler-room spaces. The propulsion is by twin screws, and with forced draft the Blitz attained a speed of 18 knots. Their torpedoes were of the Schwartzkopff type, discharged from a fixed tube in the bow under the ram; on deck they carry one 4¾-inch and four 3⅜-inch Krupp guns.

The most prominent torpedo-vessels now built or building are the Condor, Panther, and Scout, each of which gives its name to a class. There are four of the first named type, all built in French naval dockyards (see Plate V, Faucon). The title ship, launched on May 17, 1885, is a twin-screw steel vessel, of 1,270 tons displacement, 216 feet long, 29 feet 2 inches beam, 15 feet 5 inches draught. The hull is divided into ten water-tight compartments, has a steel deck near the load-line, and carries a protective belt of cellulose between wind and water. It is expected that with natural draft 2,000 I. H. P. will be developed, and with forced draft 3,200, which will probably drive her 17 knots. The sail area is reduced to what can be spread on three light fore-and-aft rigged pole masts. The armament consists of five tubes, two being forward with a train of 20 degrees on the bow, one aft, and one on each side, five 4-inch B. L. R., and six machine guns.

The Panther (Plate V) and a sister ship, the Leopard, were ordered in 1884 by the Austrian Government from the English firm of Armstrong, Mitchell & Co. The former, launched June 13, 1885, is 224 feet long, 34 feet broad, and displaces 1,550 tons on a mean load draught of 14 feet. The hull is of steel, with many bulkheads, a deck of the same material covers the boilers, and strong shields are placed about the cylinders which are vertical, inverted. The boilers are almost completely enveloped in coal, and the engines are protected laterally in the same way. The conning tower forward is armored. The propulsion is by twin screws, worked by triple expansion engines, and the mean speed of six runs on the measured mile, with natural draft, was 17.6 knots, which was also maintained for four consecutive hours; with forced draft an average of 18.4 was made for six runs on the official trial; since that time she has made 18.9. The battery consists of four long-range Krupp guns in sponsoned turrets, and a large number of rapid-firing Hotchkiss. There are four torpedo-tubes, one being in the stem, without train, above water.

The Scout, the first of her class, is a steel twin-screw torpedo cruiser of 1,450 tons, built for the British navy by Messrs. J. & G. Thomson, and launched July 30, 1885. Her dimensions are length, 220 feet; beam, 34 feet 3 inches; draught, 14 feet. She is subdivided into many compartments, and has a ⅜-inch steel deck over the engines and boilers, with 5 to 7 feet of coal on either side. On trial the speed attained with natural draft was 16.26 knots for four hours; with forced draft the mean of four runs was 17.6, the I. H. P. being 3,350; this power was developed with only 300 tons of machinery. The torpedo armament consists of eleven tubes, two fixed in line with the keel forward (one being under water), one aft, and four on each side capable of train; twenty torpedoes are carried. There are four 5-inch rifles on central pivot carriages in sponsoned half-turrets, and eight Nordenfeldts. The conning-tower has 3 inches of armor.

Six other "Scouts" are building by the same firm. As illustrated by the Archer (Plate V), launched in December, 1885, they are 5 feet longer, 2 feet broader, and displace about 1,630 tons. They will carry ten torpedo-tubes, two of which are under water, and a battery of six 6-inch and eight machine guns. At the preliminary trials the Archer made 18 knots, developing more horse-power than had been expected. Their fuel capacity is expected to carry them six days or 2,600 miles at full speed, and at 10 knots twenty-nine days or 7,000 miles.

These vessels, partaking more and more of the nature of cruisers, from their great coal endurance, sea-worthiness, and habitability, attained their many good qualities at the partial sacrifice of the handiness that is so neccessary for torpedo and anti-torpedo work. To remedy this a smaller and possibly faster type of vessel had been laid down in France. The Bombe (Plate V), the first of a class of eight, was launched by the Société des Forges et Chantiers, Havre, on April 16, 1885. She is 180 feet long between perpendiculars, with 21½ feet beam and 6 feet draught; displacement, 321 tons. The hull, which is very lightly built, the skin being nowhere bullet-proof, is subdivided by eight transverse steel bulkheads, extending to the upper deck, in which there are no doors nor openings except for pipes, shafting, &c.; a fore and aft bulkhead also extends through the engine-room, and two steel decks run the entire length of the ship, the upper one being turtle-backed; a belt of cellulose also extends fore and aft at the water-line. In each compartment there is a siphon ejector, which draws out over 40 tons of water an hour.

In the forward compartment are two tubes, one on each side of the stem, and six torpedoes; on deck are two Hotchkiss revolving cannon forward, with all-round fire, and one amidships aft; also two 4-inch B. L. R., one on each side with 180 degrees train from right ahead to right aft. On the bridge are two electric search-lights.

The twin screws are driven by horizontal, three-cylinder, compound engines; the fire-room is air-tight to secure forced draft, and a speed of 18 knots has been attained. Ordinarily the coal supply will be 46 tons, but storage can be provided for more. There are three masts fore-and-aft rigged.

In England this type is represented by the Grasshopper class now building (Plate V). The title ship laid down in October, 1885, is 200 feet in length, 23 feet 8 inches beam, 440 tons displacement. She is to be propelled by twin screws, and a speed of 19 knots is expected. The torpedo-battery will consist of one tube forward, one aft, and two amidships; for attacking torpedo-boats she is to carry probably one 4-inch B. L. R. forward, and six 3-pounder R. F. guns.

A somewhat larger vessel, the Landrail, of 785 tons displacement, was launched at the Devonport dock-yard in January, 1886. She is 195 feet long, by 28 feet broad, and draws 11 feet, and has a protective deck throughout, with special 1-inch steel plating at the torpedo and gun ports. The armament will consist of one 6-inch and three 5-inch B. L. R., four machine guns, and five torpedo tubes, one firing ahead, one on each bow, and one on each quarter; the heavy guns and torpedoes can be fired from the conning tower.

The appearance of the Bombe and class attracted the attention of the naval administration in Spain, which resulted in an order being soon given to Messrs. Thomson for a torpedo-boat destroyer 180 feet long, of 350 tons. She will only carry two torpedo-tubes forward and one aft, one 3½-inch gun forward, four 6-pounder Hotchkiss, and two Nordenfeldts. The enormous speed of 22 knots is aimed at, the motive power being furnished by locomotive boilers and transmitted by triple expansion engines intended to develop 4,000 I. H. P. Boilers and engines are entirely surrounded by coal, and the latter have in addition a 1-inch steel shield; a 1¾-inch steel bulk-head also extends athwartships forward of the boilers. The coal endurance is estimated at 4,000 knots at 10 knots an hour.

The most remarkable development of machine-gun fire on board torpedo-boat catchers is illustrated by the projected battery of two 600-

ton torpedo-vessels building at the Baltic Works, St. Petersburg, for the Russian navy. Their principal dimensions are length, 230 feet; beam, 24 feet; draught, 9 feet. The estimated I. H. P. is 3,500 and speed 20 knots. The coal capacity will be sufficient for 2,000 knots at 12 knots. The engines are three-cylinder, vertical, driving a single screw. They are to have four fixed broadside, two bow, and one stern launching-tubes, and seven spare torpedoes are to be carried. The gun armament is to consist of eight 47-millimetre and sixteen 37-millimetre H. R. C. These will not be shielded, but the eight 47-millimetres will be in light sponsoned towers on main deck, and the others on the upper deck and bridge. A curved protective deck is to extend from end to end over the machinery, dipping down below the water line forward and aft. Further protection is to be afforded the boilers by coal, which will not be used except in cases of final necessity.

Although every type of existing torpedo-vessel may not be included in the preceding account, enough has been said to show the tendency in European countries.

As for torpedo-boats, any account of them becomes antiquated in two months; not a few firms can and do turn them out at the rate of one a week. The extreme importance of this arm had been manifest from the first, when maritime nations built and bought them right and left; and the wonderful celerity with which types and details were worked out and improved upon was the natural result of the tremendous international competition that responded to the demand. Even in England, the pioneer, which has from the first occupied the unique and proud position of perfect independence in this industry, whose builders have sold to every maritime country of continental Europe, to Japan, to most of the South American countries, and to the British colonies—even in England a perhaps not unneeded spur was applied by the appearance of the one stranger purchased by the Admiralty. All other nations have bought in foreign markets, though some are well equipped at home. France and Germany have now assumed the same position as England and vie with her in foreign orders; but Russia, Turkey, and Spain, while building at home, each buy from England, Germany, and France. In Italy, several firms have effected good results, but English and German builders also help arm that country; while the last British contribution to the Austrian flotilla has been copied by their own Admiralty. Thus it is that the leading firms in various countries, by adding each a share to the sum of mechanical improvements, have combined to make the present productions possible. And these boats have now become simple marketable articles of export, the various firms having ordinary business schedules of prices, so much for such a length, with a certain speed and endurance, the cost varying with each quality; for instance, a boat 140 feet long, making 22 knots, and with a coal endurance of 3,500 miles at 10 knots, costs about $60,000; for a length of 110 feet and speed of 19 knots, the price would be about $45,000.

That the sphere of the torpedo-boat on the open sea is limited to those of large size has been commented upon above. The utility of second-class boats, however, cannot well be disputed, and there are conditions limiting their size now when used for coast defense, as there were when they were designed to be carried by sea-going battle-ships. These conditions now are the length, breadth, and depth of canal-locks, and the breadth of track and radius of curve of railways. In the early days of her torpedo armament Denmark kept a careful eye on the problem of transporting her boats by rail, so as to be able to send them safely and promptly to any threatened point. Last summer the passage of No. 68 across France by canal from the Bay of Biscay to the Mediterranean did not fail to be of interest, which was quickened by the fact of several others having been built of a size to make that same trip. Lastly, in Russia, fifty torpedo-boats were forwarded in August, by rail, river, and canal, from the Baltic to the Black Sea.

All countries are not so situated and circumstanced geographically, physically, and politically as to make this quality one of importance, but it seems peculiarly applicable to the United States, whose lake coasts are in such defenseless condition. From the Atlantic coast means of transportation to Lake Erie are furnished by the Erie Canal and the Pennsylvania Railroad. The locks of the canal are 110 feet by 17 feet 6 inches by 7 feet depth; but 102 feet is the greatest length that can be taken through. That limits the size of boat at once.

By rail, on the other hand, a length up to 150 feet could be taken, but the breadth of beam is limited by the breadth of the track and the curves and obstructions. Twelve feet might be managed with very careful blocking and shoring; but for that the boat would have to be carried nearly on her beam ends, which would be dangerous and unadvisable in view of the exceedingly light scantling of that class of vessel. The greatest beam that could be carried without serious difficulty or danger would be about 11 feet, and as the proportions of these boats do not now exceed nine beams to the length, as a rule, this would give 100 feet as the practicable length, or about the same size as the Erie Canal will take, and with much more dangerous conditions of transit.

In the West, the Illinois and Michigan Canal, 96 miles long, forms a water communication between Lake Michigan and the Mississippi River. The canal itself is 6 feet deep; the locks are 110 feet by 18. The greatest dimensions admitted are 103 feet in length and 4 feet 8 inches draught; but a draught of 5 feet can easily be taken through. Here again the size is limited by the length of the locks, as the draught of the largest boat could be reduced to 5 feet by keeping a small supply of coal on board, by tipping, or if necessary by the use of camels or empty barrels.

The line of interior water-ways along our Atlantic and Gulf coasts also points out to what advantage torpedo-boats could be employed by the United States in defensive operations, and suggests the thought that here more than anywhere else would be the true field for the utmost development of this remarkable type of vessel.

The following tables give a chronological statement of the various salient features of size, speed, endurance, safety appliances, offensive and defensive power, handiness, &c., that have successively appeared in the development of modern torpedo boats and vessels.

Development of torpedo-boats.

Year.	Length.	Displacement.	Maximum speed.	Endurance in knots at moderate speed.	Torpedoes.	Machine guns.	Built. In—	Built. For—	Remarks.
1863	35		4		1 spar		United States	Confederacy	Submarine and surface boat; built of iron; hand propeller.
1863	60		7		1 spar		do	do	Cigar-shaped; steam power.
1864					1 spar		United States	United States	Steam launches; exposed to falling water and musketry.
1864	84	207	5		1 spar		do	do	Five inches of armor; spar under water.
1873	57	7¼	14.97		1 towing		England	England	Steel; musket-proof shutters; forced draft under bars; screw abaft rudder.
1874	55		14		1 spar		do	Argentine Republic.	Pumps run off main engine.
1875	67		18.2		2 spars		do	Austria	All inclosed; steel; air pressure in closed fire-room.
1877	77		18		1 tube		do	Italy	A little more freeboard than before.
1877	87½		18.5		1 movable tube		do	England	With improved screw; made 19 knots in 1881; three torpedoes carried.
1877	87						do	France	Screw forward of rudder; under water metal galvanized; spark-catching apparatus.
1878	66		18				Germany	Russia	Higher out of water than English; behaved well at sea.
1878							England		Forward rudder; steam steerer; supplementary engines for fans, pumps, &c.; side ports in place of smokestacks.
1879	86		21.93		1 movable tube		do	England	Safety arrangement to keep steam out of fire-room; trial light; smokestacks fitted to turn down.
1879	59½	8	16		None		United States	do	Coil boiler; screw and rudder underneath; great manoeuvreing power.
1879	63	10½	17.25		Side frames		England	do	Second-class boat; locomotive boiler; device for raising steam in nine and one-half minutes.
1879	100	48	22.16	1,000	2 fixed tubes		do	Russia	Trial flying light; ram bow; steamed to Nikolaeff.
1880	90½		21.75				do	England	Trial flying light.
1881	100		22.46		2 fixed tubes		do	Italy	Trial flying light; 1,280 feet piston speed without oil; arrangement to keep water out of fires; ejecting power equals displacement in seven and three-fourths minutes.
1881	110	52½	19.91	1,200	2 fixed tubes	1	do	Norway	Speed loaded for three hours; four 19-foot Whiteheads.
1882	110	52	20.3	1,200	2 fixed tubes		do	Brazil	Speed loaded for three hours; tubes entirely inside bow; sailed to Brazil.
1882	108	48	20.62		2 fixed tubes		France	France	Speed for three hours on 43 tons displacement; coal consumption, 2.37 pounds per I. H. P. per hour.
1883	113	60	19	1,000	2 fixed tubes	2	England	Russia	Eleven compartments; electric search light.
1884	100	35	21.4				Italy	Italy	Trial light.
1885	125		20.9	2,000	5 tubes	2	England	England	Two tubes at each tower on turn-tables; search light.
1885	124		21.53	2,100	2 tubes	2	Germany	Spain	Triple expansion engines; machinery weighs 34 tons; indicates 1,000 H. P.
1885	101½	43	20.3		2 tubes, 1 spar	2	France	Turkey	Hydraulic buffer and whiskers forward; tubes fixed forward.

1885	94		21. 7	800	None	None	United States	Yacht Club	Wood, with iron bracing; coil boiler; machinery weighs 10 tons; indicates 450 H. P.; can stow coal for 2,400 miles at 9 knots.
1885	135	87	22. 4	2, 000	2 fixed tubes	2	England	Austria	Trial loaded; flying light, made 24 knots; no spare torpedoes.
1885	150	125	20. 8				do	England	"Turn about" system; turns in 1½ lengths.
1886	140				4 tubes	Several	do	Italy	Two tubes on turn-table amidships, diverging 6 degrees.
1886	164		22. 50			Several	Germany	China	Estimated speed; triple expansion engines; one locomotive boiler, 1,500 I. H. P.
1886	166	180	19		4 tubes	Several	England	Japan	Estimated speed; twin screws; 1-inch steel over machinery.

Development of torpedo-vessels.

Year.	Length.	Displacement.	Maximum speed.	Torpedo fittings.		Guns.	Built.		Remarks.
				Under water.	Above water.		In—	For—	
1874	173	720	11.4	3 spars		1 15-inch; 4 Gattling	United States	United States	4½-inch armor on bows; gun fixed in line of keel; Fowler wheel.
1874	170	800	10.6	5 spars		None	do	do	5-inch armor at water line; 9-inch on smokestack; twin screws.
1876	197	975	16	2 tubes		4 B. L. R.; 4 machine	England	Germany	Twin screws.
1882	245	1,380	18	1 tube		5 B. L. R.	Germany	do	Do.
1885	216	1,270	17		5 tubes	5 B. L. R.; 6 machine	France	France	Estimated speed; twin screws; steel deck near load-water line; belt of cellulose.
1885	224	1,550	18.9	2 tubes	3 tubes	4 B. L. R.; many Hotchkiss.	England	Austria	Twin screws; triple expansion engines; steel deck over machinery.
1885	220	1,450	17.6	1 tube	10 tubes	4 B. L. R.; 8 machine	do	England	Twin screws; steel deck over machinery.
1885	225	1,630	18	2 tubes	8 tubes	6 B. L. R.; 8 machine	do	do	Twin screws; 2,600 knots at full speed; 7,000 knots at 10 knots.
1885	180	321	18		2 tubes	2 B. L. R.; 3 machine	France	France	Twin screws; two steel decks; belt of cellulose.
1885	180	350	22		3 tubes	1 B. L. R.; 6 machine	England	Spain	Twin screws; speed estimated; coal and 1-inch steel over machinery; can make 4,000 miles at 10 knots.
1886	200	440	19		4 tubes	1 B. L. R.; several machine.	do	England	Twin screws; speed estimated.
1886		600	20			24 machine	Russia	Russia	Single screw; speed estimated.

A STUDY OF TORPEDO-BOATS.

By J. A. Normand, of Havre.

[Translated from the French by Ensign W. L. Rodgers, U. S. N.]

The following calculations relative to torpedo-boats are similar to those I published in 1877 on cruisers and squadron scouts.*

Although such calculations are founded on hypotheses, some of which are open to discussion, it is free to suppose that with little departure from the vessel chosen as a type the results arrived at have a certain reliability.

The principal assumptions are as follows:

1. *The hull and under-water body remain geometrically similar with varying speeds and dimensions.*

2. *Efficiency does not vary with the absolute size and remains constant when near the limit of speed.*

These hypotheses, which are certainly wrong for large vessels, appear admissible for the torpedo-boats. In support of this opinion the following facts may be cited:

The efficiency of the two wonderful torpedo-boats furnished to the French Government by Thornycroft in 1876 is not less than that of considerably larger boats.

On the other hand, the efficiency of the torpedo-boats of the type of No. 60 seems to improve slightly beyond the speed of 16 to 17 knots. Perhaps there is a slight lifting, which is evidently more likely with small vessels than with large ones, for with the latter such an effect can take place only at the very highest speeds.

3. *The weight of hull and armament varies as the cube of the linear dimensions.*

For equal strengths this weight varies according to a higher power than the cube, for the rupturing moments increase as the fourth power of the dimensions while the resisting moments vary only as the cube;

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* Étude géométrique sur les Croiseurs d'Escadre. Paris. Gauthier-Villars.

but on the other side, the thickness of certain parts of the hull may be reduced in large vessels on account of their endurance.*

4. *The weights of machinery per indicated horse-power at the maximum speed do not vary with their powers.*

Large engines are economical with regard to the weight of parts, of tools, and of accessories; on the contrary, the speed of rotation is favorable to small engines.

As for the boilers, small engines are certainly more susceptible of being pressed than large ones. (It is true that increase of evaporative power may be obtained, as in the torpedo dispatch boats, by increasing the number of boilers similar to those of smaller vessels.) But the efficiency of fuel increases with the size of engines and boilers.

In point of fact, between the limits of the ordinary or probable size of torpedo-boats; that is to say, between 15 and 200 tons, the law may be considered exact. The following table shows the relative specific weights of very light types:

Class.	Maximum power with forced draught.		Ratio of H. P. to weight of motor.
	French.	English.	
	Horse-power.	Horse-power.	
Coast-guard torpedo-boats	575	566.9	1.00
Torpedo-launches	150	148.9	1.25
Torpedo dispatch boats	1,900	1,873.4	1.17
Torpedo-cruisers	3,200	3,155.2	3.20

As is seen, for machinery of similar types—that is, for vertical high-speed engines and locomotive type of boilers, the weights per horse-power vary according to a continuous curve, whose minimum ordinate is near the coast-guard torpedo-boat.

The change of type of machinery and boilers in the torpedo-cruisers is the reason for the sudden rise of the curve.†

These facts are of great importance in designing. Whatever horse-power may be designed between 150 and 1,500 horse-power, and particularly between 400 and 1,000 horse-power, the specific weight, *i. e.*, $\frac{\text{weight}}{\text{H. P.}}$, is sensibly constant; as I assume in the following calculations.

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* Deceptions often occur regarding the advantages of absolute size. For example, there is reason to suppose, that leaving aside all commercial considerations, the size of the latest transatlantic steamers is exaggerated; for in large vessels the weight of the hull, both in theory and practice, varies for equal strengths according to a power higher than the cube of the linear dimensions, as the consideration of endurance may then be neglected.

It does not seem impossible in particular cases that the advantages of increased size are negative.

† The ratio of the weight of water in the boilers at the maximum speed is five times greater in the cruisers than in the coast-guard boats.

The questions of armament, of maximum speed, of coal endurance, and of the partial protections of torpedo-boats are to-day universally studied. As one or another of these elements is increased, the advantage is clearly exhibited in the offensive or defensive power; but what does not appear is the resulting increase in absolute size, and therefore of the cost and of the crew, the other factors remaining constant.

For example, what is the increase of size which must be given to a typical torpedo-boat to carry a certain weight of battery without decreasing her maximum speed or her coal endurance. It will be seen farther on that the increase to be allowed for is about four times that of the increased weight of battery.

The calculations which follow indicate the law of variation in size in terms of the specific weights, of the speed, of the coal endurance, and of weights independent of the displacement, but the results obtained are exact only so long as the general type of boat is unaltered.

NOTATION.

D = load displacement in kilograms, including the weight of coal necessary to make a distance of R. miles at. the reduced speed of V knots.

U = maximum speed on 3 hours' trial in knots.

R = coal endurance in knots at the reduced speed V.

V = reduced speed in knots to which the coal endurance R refers.

m' = coefficient of efficiency at reduced speed by the formula:

$$v=m' \sqrt[3]{\frac{F}{D^{\frac{2}{3}}}}$$ [*]

F = I. H. P. at the maximum speed U in H. P. of 75 kilogrammetres.

F' = I. H. P. at the reduced speed V in H. P. of 75 kilogrammetres.

a = ratio to the displacement D of the sum of the following weights. Hull and accessories, pumps with their pipes, steering-gear, capstan, collision-buffer, anchors and cables, masts, sails, and rigging, awnings, sweeps, leak-stoppers.

h = ratio to the $\frac{2}{3}$-power of the displacement—that is, to $D^{\frac{2}{3}}$—of the sum of the following weights: Crew with clothing, boats, galley, and gear. If necessary there must be added to this sum, as weights varying in the same ratio, the armor covering a constant proportion of the hull, as, for example, the space occupied by the motor and by the crew.[†]

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[*] The efficiency referred to the $\frac{2}{3}$ power of the displacement is more constant, when the proportions of the dimensions of the hull vary, than when referred to the midship section.

[†] The thickness of armor is the difference between the scantling actually employed and that which would have been sufficient were only the strength of the hull considered.

c = ratio of the weight of the motive machinery (in kilograms) to the maximum power F.

e = consumption of coal per H. P. per hour at the speed v (in kilograms).

f = ratio of the weight of water and provisions to $RD^{\frac{2}{3}}$; that is to say, to the product of the coal endurance and the $\frac{2}{3}$-power of the displacement.

P = sum in kilograms of the following weights which are independent of the displacement: Torpedoes, discharging-gear, charging-gear, electric lights, battery, and ammunition. If necessary there must be added to this sum as a part of its total, as being also independent of the displacement, the armor which covers certain parts of constant dimensions, as, for example, the launching-tubes, the torpedoes, and the conning-tower.

A torpedo-boat may be regarded as a vessel capable of reaching the maximum speed U, of making a passage of R knots at the reduced speed v, and of carrying a weight P, independent of the displacement, in torpedoes, charging- and launching-gear, electric lights, guns, and ammunition.

In certain cases, and from the most general point of view, the displacement must include, besides, armor covering a certain proportion of the hull (for instance, the space occupied by the motor and by the crew), and armor covering surfaces independent of the absolute size of the boat, as, for example, the launching-tubes, the torpedoes, and the conning-tower.

These various weights may be expressed as follows:

1. Hull and accessories, pumps and piping, steering-gear, capstan, collision-buffer, chains and anchors, masts, sails, rigging, awning, sweeps, leak-stoppers.

This weight, varying as the cube of the linear dimensions, may be expressed as aD.

2. Crew and clothing, boats (equipped), galley, and gear; and, if necessary, the armor covering a certain proportion of the hull.

The weight, varying approximately as the square of the linear dimensions, may be expressed as $bD^{\frac{2}{3}}$.

3. Motive machinery.

We have

$$U=m\sqrt[3]{\frac{F}{D^{\frac{2}{3}}}}$$

whence

$$F=\frac{U^3D^{\frac{2}{3}}}{m^3}$$

The weight of the machinery, which is equal to cF, is therefore expressed by

$$c\frac{U^3}{m^3}D^{\frac{2}{3}}$$

4. Combustible.

$$v=m'\sqrt[3]{\frac{F'}{D^{\frac{2}{3}}}}$$

whence

$$F'=\frac{v^3D^{\frac{2}{3}}}{m'^3}$$

The weight of coal burnt per hour, that is, to run v knots, is

$$eF'=\frac{ev^3D^{\frac{2}{3}}}{m'^3}$$

and the weight of coal necessary to run R knots, is

$$\frac{R}{v}eF'=\frac{eRv^2D^{\frac{2}{3}}}{m'^3}$$

5. Water and provisions.

This weight, proportional to the square of the linear dimensions, as is the crew, and to the endurance, is expressed by $fRD^{\frac{2}{3}}$.

6. Torpedoes, charging- and launching-gear, and electric lights, and the armor of surfaces independent of the absolute size of the boat.

This weight, being by assumption independent of the size of the boat, may be expressed as P.

The sum of all these weights must be equal to the load displacement, whence

$$D=aD+bD^{\frac{2}{3}}+\frac{cU^3D^{\frac{2}{3}}}{m^3}+\frac{eRv^2D^{\frac{2}{3}}}{m^3}+fRD^{\frac{2}{3}}+P$$

and hence

$$(1)\quad . \; . \; . \; . \quad D-\frac{b+\frac{c}{m^3}U^3+\left(\frac{ev^2}{m'^3}+f\right)R}{1-a}D^{\frac{2}{3}}-\frac{P}{1-a}=0$$

This equation is of the form

$$D+AD^{\frac{2}{3}}+B=0$$

an equation of the third degree whose solution gives—

$$(2)\;.\;.\;D=\left(-\frac{A}{3}+\sqrt[3]{\frac{B}{2}-\frac{A^3}{27}+\sqrt[2]{\frac{BA^3}{27}+\frac{B^2}{4}}}+\sqrt[3]{-\frac{B}{2}-\frac{A^3}{27}\sqrt[2]{\frac{BA^3}{27}+\frac{B^2}{4}}}\right)^3$$

Let us apply the above formulas to a torpedo-boat which I am now building, and which I will call type A.

To simplify the calculations the armor will be considered as nothing, although, perhaps, certain thicknesses might be diminished without compromising the strength.

*Principal dimensions.**

	French units.		English units.	
Length from the stem to the stern-post at the water-line	Metres	40. 75	Feet	133. 70
Extreme beam	Metres	3. 33	Feet	10. 93
Depth of hold from the upper side of keel-plate to under the deck (mean)	Metres	2. 65	Feet	8. 69

Results of calculations.

	French units.		English units.	
D, load displacement	Kgs.	66, 320. 00	Pounds	146, 210. 40
$D^{\frac{2}{3}}$		1, 638. 40		2, 775. 35
$D^{\frac{1}{3}}$		40. 48		52. 68
U, maximum speed at load-draught	Knots	19. 00	Knots	19. 00
F, corresponding maximum I. H. P.		575. 00		566. 95
m, in the formula $U=m\sqrt[3]{\frac{F}{D^{\frac{2}{3}}}}$		26. 94		32. 26
m^3		19, 550. 00		33, 577. 50
v	Knots	11. 00	Knots	11. 00
F' I. H. P. corresponding to V		102. 30		100. 87
R	Sea-miles	1, 350. 00		
m', in the formula $v=m'\sqrt[3]{\frac{F'}{D^{\frac{2}{3}}}}$		27. 68		33. 21
m'^3		21, 210. 00		36, 622. 60
e, coal consumption per I. H. P. per hour at the speed of 11 knots	Kgs.	1. 00	Pounds	2. 23

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* The French units have been converted into English by Assistant Naval Constructors Gatewood and Nixon.

Specification of weights (assumed).

	French units.	English units.
	Kgs.	*Pounds.*
1. Hull and accessories, pumps, steam-steering gear, capstan, collision-buffer, anchor and chains, masts, sails and rigging, awning, sweeps, leak-stoppers	26, 380	58, 157. 9
2. A wooden boat and a Berthon boat, 15 men with clothing, galley and gear, mess gear	1, 940	4, 277. 0
3. Motive machinery with boilers filled, condenser, and fresh-water feed-tank, spare circulating-pump, donkey-pump, feed-pump, ventilators, piping, tools, stores and supplies, reserve water in tanks, distiller	20, 250	44, 643. 6
4. Coal necessary for 1,350 miles, at 11 knots	12, 550	27, 668. 0
5. Water and provisions, with tare, for 8 days	1, 000	2, 204. 6
6. Four 5.75 m. torpedoes, launching tubes, 2 Hotchkiss cannon and ammunition, with non-recoil mounts and braces to the hull under the guns	4, 200	9, 259. 4
Total equal to load displacement D	66, 320	146, 210. 4

We now have

	French.	*English.*
$a=$	$\frac{26380}{66320}=0.3977$	$\frac{58157.9}{146210.4}=0.3977$
$b=$	$\frac{1940}{1638.4}=1.184$	$\frac{4277}{2775.35}=1.541$
$c=$	$\frac{20250}{575}=35.22$	$\frac{44643.6}{566.95}=78.74$
$f=$	$\frac{1000}{1350\times1638.4}=0.000452$	$\frac{2204.6}{1350\times2775.35}=0.000588$

These values, substituted in equation (1), give for torpedo-boats of type A

(3) (French) $D-(1.966+0.00299U^3+0.01018R)D^{\frac{2}{3}}-1.66P=0$

(English) $D-(2.558+0.003885U^3+0.0132R)D^{\frac{2}{3}}-1.66P=0$

Equation (1) permits the calculation of the change of displacement for changes in U, R, and P when the changes are not large. It will be sufficient to differentiate with respect to D and each of the three other variables in succession.

1. Let us differentiate with respect to D and U.

$$(4) \quad \frac{\varDelta D}{\varDelta U}=\frac{9\frac{c}{m^3}U^2D^{\frac{2}{3}}}{1-a+\frac{2P}{D}}$$

2. Differentiating with respect to D and R,

$$(5) \quad \frac{\varDelta D}{\varDelta R}=\frac{3\left(\frac{ev^2}{m'^3}+f\right)D^{\frac{2}{3}}}{1-a+\frac{2P}{D}}$$

3. Differentiating with respect to D and P,

$$(6) \quad \frac{\varDelta D}{\varDelta P}=\frac{3}{1-a+\frac{2P}{D}}$$

These three equations give for type A

	French.	*English.*
$\frac{\varDelta D}{\varDelta U}=$	13150.00	28945.40
$\frac{\varDelta D}{\varDelta R}=$	41.30	91.06
$\frac{\varDelta D}{\varDelta P}=$	4.12	4.12

These figures may be interpreted as follows:

In torpedo-boats of type A, and in those differing but slightly from that type, a change of half a knot in the maximum speed of 19 knots, necessitates a change of the same sign in the displacement, amounting to 6½ tons if the endurance and weights of torpedoes and battery are unchanged.

*A change of 100 miles in the coal endurance of 1,350 miles, necessitates a change of the same sign in the displacement of 4 tons, provided the maximum speed and the weight of torpedoes and battery are unchanged.**

A change of 1 ton in the weights of torpedoes and battery necessitates a change of the same sign in the displacement of 4 tons, if the maximum speed and coal endurance are unchanged.

The derivative $\frac{\Delta D}{\Delta P}$ differs from the other two derivatives $\frac{\Delta D}{\Delta U}$ and $\frac{\Delta D}{\Delta R}$ in that it varies little with changes in the displacement. The simple law which it expresses, applies not only to weights independent of the displacement, but also all small changes whatever in any of the component weights of the boat, since such changes may, within limits, be considered as constant.

The derivative $\frac{\Delta D}{\Delta P}$ may therefore be interpreted thus:

In torpedo-boats, whatever may be their maximum speed or their coal endurance, and hence their displacement, a small change in any weight on board implies a change of the same sign in the displacement about four times greater, if the maximum speed and coal endurance are to remain the same.

Thus, for example, let us suppose that we may diminish the thickness of the plates of the hull of the type A of torpedo-boats by one-twentieth or by one-fourth of a millimeter for the plates of 5 millimeters, by 0.15 millimeter for plates of 3 millimeters, and that all thicknesses are reduced in the same proportion; in other words, the design is to be carried out with weak scantlings, a frequent occurrence in naval construction; this lightening would result in a reduction of weight equal to

(French) $\frac{1}{20} \times 26{,}380$ kilograms $= 1{,}319$ kilograms
(English) $\frac{1}{20} \times 58{,}157.9$ pounds $= 2{,}907.9$ pounds

and in a possible diminution in the total displacement of

(French) $1{,}319 \times 4.12 = 5{,}434$ kilograms
(English) $2{,}907.9 \times 4.12 = 11{,}980$ pounds

or one-twelfth of the displacement.

To obviate all uncertainty relative to a result apparently so singular, let us follow out the calculation exactly.

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* It is evident that 1,350 miles does not represent the maximum coal endurance. The supply of coal may be greatly increased at departure. If the state of the sea or the need of reaching the maximum speed requires it, the surplus may be thrown overboard; this could not be done in a large ship.

If we represent by M the quotient of the sum of the weights proportional to the two-thirds power of the displacement (that is, crew, machinery, fuel, provisions, &c.), divided by $D^{\frac{2}{3}}$, equation (1) may be written

$$(1-a)D-MD^{\frac{2}{3}}-P=0$$

and differentiating with respect to a and D we have

$$\frac{\Delta D}{\Delta a}=\frac{D}{1-a-\frac{2}{3}\cdot\frac{M}{D^{\frac{1}{3}}}}$$

In the present case

(French) $$M=\frac{1940+20250+12550+1000}{1638.4}=21.82$$

(English) $$M=\frac{4277+44643.6+27668+2204.6}{2775.35}=28.39$$

and

$$\Delta a=\frac{0.3977}{20}=0.01988$$

whence

(French) $\Delta D=272978\times 0.01988=5{,}427$ kilograms

(English) $\Delta D=601688\times 0.01988=11{,}962$ pounds

We see how important it is to reduce as much as possible all weights carried by small vessels.

The exactitude of the preceding calculations is probably sufficient for slight variations from the type, because then the fundamental hypotheses, namely, the constancy of efficiency, of the proportional weight of the hull, coal consumption, and of the weight of machinery per horse-power at the maximum speed, may be considered true. Within more extended limits the exactitude is less; nevertheless, it is not without interest to ascertain what the displacement becomes in the general equation (3) when U, R, and P vary.

The following table shows the results:

Displacements of torpedo-boats of type A in tons.

Coal endurance R at the speed of 11 knots.	FRENCH.				ENGLISH.			
	Weight P of torpedoes, battery, &c., independent of displacement.				Weight P of torpedoes, battery, &c., independent of displacement.			
	0 kilo.	5,000 kilos.	10,000 kilos.	15,000 kilos.	0 lb.	11,023 lbs.	22,046 lbs.	33,069 lbs.
Miles.	*Tons* (1,000 *kgs.*).	*Tons* (1,000 *kgs.*).	*Tons* (1,000 *kgs.*).	*Tons* (1,000 *kgs.*).	*Tons.*	*Tons.*	*Tons.*	*Tons.*
[I.—Maximum speed $U=18$ knots.]								
0.....	*7.3	24.8	38.8	52.5	7.184	24.41	38.19	51.67
500.....	14.7	34.0	49.7	64.1	14.468	33.46	48.91	63.09
1,000.....	25.9	46.6	63.8	79.9	24.600	45.86	62.79	78.64
1,500.....	41.6	63.4	82.0	99.2	40.940	62.40	80.70	97.63
2,000.....	62.8	85.4	105.0	123.5	61.810	84.05	103.34	121.55
[II.—Maximum speed $U=19$ knots.]								
0.....	11.4	30.0	45.1	59.6	11.22	29.53	44.39	58.66
500.....	21.0	41.2	57.9	73.3	20.67	40.55	56.98	72.14
1,000.....	34.8	56.2	74.3	90.9	34.25	55.31	73.13	89.46
1,500.....	53.8	76.1	95.4	113.3	52.95	74.90	93.89	111.51
2,000.....	78.6	101.5	121.8	140.8	77.36	99.90	119.88	138.67
[III.—Maximum speed $U=20$ knots.]								
0.....	17.4	37.1	53.2	68.2	17.12	36.51	52.36	67.12
500.....	29.8	50.8	68.5	84.6	29.33	50.00	67.42	83.26
1,000.....	46.9	68.9	87.9	105.4	46.16	67.81	86.51	103.76
1,500.....	69.7	92.4	112.4	131.1	68.60	90.94	110.62	129.03
2,000.....	98.9	122.1	143.1	162.8	97.34	120.17	140.84	160.23

* A torpedo-boat of 7.3 tons, similar to type A, would have the following dimensions: Length, 19.50 metres (63.98 feet); beam, 1.60 metres (5.25 feet); depth, 1.27 meters (4.17 feet). These proportions are in admissible in so small a boat. The figures of 7.3 tons and some others little greater are entered in the table only to show the law of the change.

The time a torpedo-boat remains at full speed is usually so small compared to that it remains at reduced speed, that it has been possible to neglect it in the expression for coal endurance.

If, therefore, the action of the boiler, the strength of the mechanical parts and the friction of machinery permitted it, the power, and consequently the maximum speed, might be indefinitely increased by means of the blower, without any appreciable change in the coal endurance. Although this appears difficult under present conditions, it may be admitted that the weight of machinery per indicated horse-power at the maximum speed will sooner or later be decreased, and it is interesting to ascertain the consequent changes in displacement.

Let us suppose that this weight may be reduced to three-fourths of what it is in type A; it would then be 26.41 kilograms instead of 35.22 kilograms, and the general equation would be

(7) . . . (French) $D-(1.966+0.002243U^3+0.01018R)D^{\frac{2}{3}}-1.66P=0$
(English) $D-(2.558+0.002914U^3+0.0132R)D^{\frac{2}{3}}-1.66P=0$

The following table gives the rēsults of this equation at the maximum speed $U=19$ knots:

Displacement of torpedo-boats of type A of the maximum speed $U=19$ knots, the weight of machinery per I. H. P. being reduced to three-fourths of its present weight.

Coal endurance R in miles at the speed of 11 knots.	FRENCH TONS.				ENGLISH TONS.			
	Weight P of torpedoes, battery, &c., independent of displacement.				Weight P of torpedoes, battery, &c., independent of displacement.			
	0 kilo.	5,000 kilos.	10,000 kilos.	15,000 kilos.	0 lb.	11,023 lbs.	22,046 lbs.	33,069 lbs.
0.....	5. 2	21. 9	35. 3	47. 6	5. 10	21. 6	35. 0	46. 7
500.....	11. 3	30. 0	45. 0	58. 9	11. 1	29. 5	44. 3	59. 0
1, 000.....	20. 9	41. 4	57. 7	73. 0	20. 6	40. 8	57. 0	71. 8
1, 500.....	34. 7	56. 1	74. 2	90. 8	34. 0	55. 1	72. 8	89. 5
2, 000.....	53. 6	75. 9	95. 2	113. 0	52. 6	76. 7	93. 5	111. 2

It appears from this table that for $R=1{,}350$ miles and $P=4{,}200$ kilograms (9,259.4 pounds), or for the conditions of type A, that there might be a reduction in the displacement of more than 18 tons (17.7 English tons) when the apparent reduction in the weight of machinery did not exceed $\frac{1}{4}.20.25$ tons$=5.06$ tons ($\frac{1}{4}.19.92$ tons$=4.98$ English tons).

This reduction of one-fourth in the weight of machinery may appear much exaggerated, but it must not be forgotten that the field for improvement in the torpedo-boat is much greater than in any other class of vessels, and is yet greater for the torpedo than for the torpedo-boat. If it is admitted that the fish torpedo is now a factor as important as armor, it may be fearlessly asserted that in a few years it will be more important.

Let us now examine what reduction of displacement it will be possible to obtain by substituting liquid fuel for coal.

Let us assume that 1 kilogram of liquid fuel has the evaporative efficiency of 3 kilograms of coal, a ratio generally admitted; the 12,550 kilograms (27,668 pounds) of coal may therefore be replaced by 4,183 kilograms (9,229 pounds) of oil without diminishing the fuel endurance.

Equation (3) of type A then would become

(8) . . . (French) $D-(1.966+0.00229\ U^3+0.00389\ R)\ D^{\frac{2}{3}}-1.66\ P=0$
(English) $D-(2.558+0.00388\ U^3+0.00506\ R)\ D^{\frac{2}{3}}-1.66\ P=0$

preserving the present type of engines, and supposing that ordinary boilers can bear the extreme temperature produced by the combustion of oil, of which there is very little probability.

With the values of U, R, and P of type A this equation becomes

(French) $D-27.73\ D_{\frac{2}{3}}-6{,}972=0$

(English) $D-36.04\ D^{\frac{2}{3}}-15{,}370.6=0$

Whence

(French) $D=38.7$ tons

(English) $D=38.1$ tons

Thus the substitution of liquid fuel for coal would permit the reduction of the displacement to six-tenths of its present amount, speed and endurance remaining the same. Among other curious deductions which may be drawn from this result is that the use of liquid fuel would result in a great economy of expense in spite of its high price.

The use of oil presents this advantage, that constant steam pressure may be maintained by manipulating a cock, an advantage whose importance will be increased if we ever arrive at the use of boilers containing much less water than the present types.

Must we conclude from what precedes that liquid fuel will sooner or later be substituted for coal on board torpedo-boats? We do not think so.

Torpedo-boats are fighting craft, and from this point of view coal has exceptional qualities which cannot be rightly estimated until the penetration of rapid-firing projectiles into coal has been compared with the penetration in an equal weight of steel.

Without compromising the stability of the present torpedo-boats, a weight of coal the equivalent of from 50 millimeters to 80 millimeters of steel may be so arranged as to protect the really vital parts, the machinery, the conning-tower, and the torpedoes (buoyancy being obtained by powerful pumps, for example, of a capacity of 200 tons per hour).

This protection constitutes a valuable reserve in case of the exhaustion of the bunkers. If the state of the sea or the necessity of avoiding a fast enemy requires it, the torpedo-boat may lighten herself in a few minutes. Finally, projectiles piercing the coal do not hurt it, but oil-tanks would be rapidly emptied, no matter where they might be put.

Such are the results which may be reached with type A within the limits of habitability.

In the torpedo-boats now in service the conditions of habitability are undoubtedly defective. The principal faults are the lively motion in a seaway and the excessive internal heat caused by the sun.

It is probable that the type (A) now under consideration will be an improvement in this regard upon Nos. 63 and 64, principally by the additional of small sail-power, which will be most useful to steady the boat in a beam-sea, and which is besides indispensable to an autonomous torpedo-boat.

The spars, which may be easily unshipped, are too light by themselves to alter the period of oscillation.

To decrease the internal temperature the ordinary awnings are not enough, but there must also be an extremely light inside-plating extending from the water-line up under all the topsides; it should be open at the bottom to admit a current of air, for which exits should be provided through funnels or gratings.

The introduction of such a plating inside the living quarters and the machinery compartments, together with the necessary accessories, would weigh at least a ton in type A, which would necessitate an increased displacement of 4 tons.

Under these new conditions, or with a displacement of from 71 to 72 tons, the torpedo-boat would have a very fair degree of habitability, or at least would be much better than Nos. 63 and 64.

From the foregoing calculations, and those in the notes further on, it appears that a small variation in any of the weights making up the displacement of a torpedo-boat, of a gun-boat, of a dispatch-boat, or of a cruiser, necessitates a corresponding variation in the displacement four or five times greater, provided that the fuel endurance and maximum speed remain unaltered, and that the hull and under-water body remain geometrically similar. This result is important; it not only furnishes a simple means of making a design based on a given type, but it seems of a nature to throw some light on certain disputed naval questions.

Let us see, for example, what increment of a vessel's displacement would be required to arm her with spar-torpedoes.

The weight of the torpedo, of its spar and all its gear, windlass, guide-iron, &c., amounts in torpedo-boats of 27 metres (88.6 feet) to 1,020 kilograms (2,249 pounds), and that of the spring collision-buffer, steel defenses, &c., to 520 kilograms (1,146 pounds), or 1,540 kilograms (3,395 pounds) in all. These weights, and particularly that of the collision-buffer, must increase with the displacement.

It may be admitted that the total weight would be 1,700 kilograms (3,748 pounds) on coast-guard boats, 2,200 kilograms (4,850 pounds) on torpedo dispatch-boats, and 2,500 kilograms (5,511 pounds) on gun-boats whose bowsprits and stems offer considerable resistance which may be utilized.

The increase of displacement which would result, with equal maximum speed and fuel endurance, would be

Coast-guard torpedo-boats, $1,700 \times 4.12 = 7$ tons
Torpedo dispatch-boats, $2,200 \times 4.52 = 10$ tons
Cruising gun-boats, $2,500 \times 4.73 = 12$ tons

Does the value of spar torpedoes justify this increase? Yes, if we consider the uncertainties of fish torpedoes, the extreme delicacy of their parts, and the deep study required to use them. The addition of spar torpedoes, even on the existing Whitehead-torpedo boats, seems very desirable to many officers, although it would cause a loss of speed and fuel endurance.

This opinion is nevertheless debatable, and for this reason; one of the principal qualities of a torpedo-boat is the faculty of choosing a favorable instant for fighting. Such a time occurs at night or in special conditions of the atmosphere, as in foggy weather,* rain squalls, &c., or even in clear weather, provided the vicinity of the coast or of a battle-ship permits the torpedo-boat to approach sufficiently close to the enemy. This faculty of selecting the time of fighting is proportional to the difference of speed between the torpedo-boats and the vessels intended to chase them. A few tenths of a knot are therefore of great importance.

As for cruising gunboats (whose engines are protected by being under the water-line, which permits them to fight for an appreciable time), it must not be forgotten that they are unprotected against the heavy artillery of battle-ships or cruisers. Their spar torpedoes should therefore be mounted on themselves, rather than on their boats, for, unlike torpedo-boats, they have not the faculty of choosing their time of attack.

They would, therefore, be usually attacked by day. Under such circumstances a spar torpedo carried by a seven-knot launch, whose machinery would be disabled by the smallest shot, would be worthless.

Have we not, then, the right to believe that this weapon, so powerful and so light, should be furnished to all vessels, without exception?

We may go farther, and foresee the time when it will replace entirely the ordinary ram, which has no longer any function to fill since the use of the spar torpedo has become really practical.

The ram is greatly heavier than one or more spar torpedoes with all their accessories, which are capable of producing the same result. The ram requires greater displacement and speed, and is dangerous for the ship carrying it, because if it is low enough to be efficacious it injures the nautical qualities of the ship; it makes the movements of a vessel in harbor compromising to the solidity and water-tight conditions of the water body.

Above all it is dangerous in squadron sailing, as several accidents have proved.

On the other hand, the spar torpedo is light; its action is independent of the speed or displacement; it is active or passive at will; the spar being movable, it does not embarrass maneuvers in squadron or in port; the shock of collision which frequently follows an attack with this weapon may be absorbed by the topsides. From every point of view, the spar torpedo is superior to the ram.*

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*If it ever becomes possible, in a practical manner, to produce an artificial cloud, such as that made by heavy guns, as was so noticeable at the bombardment of Alexandria, the value of torpedo-boats will be much increased, for their great speed will permit them to assume a position to windward of the enemy.

The use of small vessels, differing little from torpedo dispatch boats in size and speed, but in which the fish torpedoes and accessories are replaced by artillery, has been lately proposed. M. Gabriel Charmes, who shares with Admiral Aube the honor of having drawn public attention to modern conditions of maritime war, thinks that such ships would be valuable auxiliaries for autonomous torpedo-boats, which they should always accompany, and that they would be useful in bombardments.

This opinion seems debatable for several reasons.

The bombardment of commercial ports by means of men-of-war only could be efficacious, but it may be hoped that in the next marine war a way may be found to avoid so serious a step. The demands of humanity are of the first importance, but putting these aside, is it not a common advantage to reduce expenses to the minimum? In fact, during hostilities it is not known which of the two belligerents will bear the consequences. Moreover, the indemnity paid to the conqueror can never compensate for his losses, and these losses will be greater as the laws of war are more severe.†

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* Already in a paper "On sea-going torpedo-boats," read on 14th of March, 1883, before the Institute of Naval Architects, I pointed out the early substitution of the spar torpedo for the ram:

"The use of the torpedo is rapidly gaining a wider range. Before long we may see it replacing the ordinary ram, that most barbarons of all weapons for vessels sailing in squadron, which has already done more harm to friends than to enemies. Should this substitution take place the ram would remain, but it would be innocuous or offensive at will. Of the three weapons now in use—gun, torpedo, and ram—the first alone can be guarded against by armor, and that by the sacrifice of money, men, speed, and handiness. Against the other two all vessels are equally vulnerable.

"If torpedo science continues to progress as it has done, it will be almost useless to protect ships at such tremendous cost against shot, leaving the immersed parts unprotected, and we may believe the time will come when fleets will consist of cruisers, torpedo-vessels, and torpedo-boats."

M. Gabriel Charmes is of the same opinion (seeRevue des Deux Mondes, March 1, 1885).

† It will perhaps be admitted that in the case of war between neighboring powers the blockade of the principal ports of the enemy by means of vessels fast enough to escape from small torpedo-boats is the safest, most economical, and most humane way of stopping commerce. Transferring trade to a neutral flag, which is sufficient protection against privateering, which is thus rendered illusory, would then be without object. The gunboats, or rather the large torpedo-boats, armed with artillery, would find a most useful field. Can a blockade of such a nature be considered effective? That cannot be asserted; but is it not evident that really effective blockades—that is, permanent ones—have become impossible since the invention of torpedoes, and that the usual interpretation of this part cf maritime rights must be modified?

In any case, and even if we were to depend only on privateering, we should try to restrict it to the neighborhood of the coasts. There, rather than on the high seas, where routes are numberless, is the probability greatest of meeting the enemy.

In short, it is only in this manner that we can make use of small fast cruisers. In case of war between distant powers, the one with a base of operations near the other would have an important advantage. Such a base can never be furnished by a fleet.

As for the functions of gunboats in a naval action, it must be remembered that in vessels in a state of violent vibration, and whose movements are extremely lively on account of the absence of masting, the fire would be bad. Left to their own resources (for convoying is always more or less uncertain) they would be without serious offensive power, while the addition of spar or fish torpedoes would greatly increase their value.

Between a vessel of 300 tons without spar or fish torpedoes and another of 310 or even 320 tons the choice cannot be doubtful.

In other words, the torpedo being the primary weapon, there is a field for torpedo-boats without cannon and for torpedo-boats with cannon. Both types should be armed with machine guns, which are the only means of defense against smaller types of torpedo-boats, or even against mere picket-boats.

NOTE.

It will be interesting to examine the value of the coefficient $\frac{\Delta D}{\Delta P}$ for vessels differing from those which form the principal subject of this paper; for example, of a large torpedo-boat now building and for a cruising gunboat.

Large torpedo-boat (Bombe class)—classification of weights (assumed).

[Weights proportional to D.]

	Kilograms.	Pounds.
Hull and accessories, masts, rigging, anchors, chains	154, 000	339, 511. 7

[Weights proportional to $D^{\frac{2}{3}}$.]

	Kilograms.	Pounds.
Boats, crew, and equipment	11, 000	24, 250. 8
Protection of hull	6, 000	13, 227. 7
Machinery complete, distiller	78, 000	171, 960. 4
Fuel	43, 000	94, 798. 7
Provisions and water	6, 000	13, 227. 7
	144, 000	317. 465. 3

[Weights independent of displacement.]

	Kilograms.	Pounds.
Torpedoes, artillery, and ammunition, apparatus for charging and discharging torpedoes, for electric light, plus the parts of the hull which belong to them. (P)	23, 000	50, 706. 0
Total equal to load displacement	321, 000	707, 683. 3

Equation 6 gives—

$$\frac{\Delta D}{\Delta P}=\frac{3}{1-\frac{154000}{321000}+\frac{2\times 23000}{321000}}=\frac{3}{0.6636}=4.52.$$

Therefore, *in the large type of torpedo-boats under consideration, a small change in any of the weights on board implies a change of the same sign in the displacement* 4.52 *times greater, provided the maximum speed and fuel endurance are to remain unaltered.*

Screw gunboat Aspic.—Classification of weights.

[Weights proportional to D.]

	Kilograms.	Pounds.
Hull complete, spar, rigging, anchors, chains, &c	252, 000	555, 564. 5

[Weights proportional to $D^{\frac{2}{3}}$.]

Boats, crew, and equipment	28, 000	61, 729. 4
Machinery complete	80, 000	176, 369. 7
Coal	52, 000	114, 640. 3
Provisions and water	25, 000	55, 115. 5
	185, 000	407, 854. 9

[Weights independent of D.]

Artillery and ammunition, plus the weight of parts of the hull belonging thereto. (P)	39, 000	85, 980. 2
Total equal to load displacement	476, 000	1, 049, 399. 6

Equation 6 gives—

$$\frac{\Delta D}{\Delta P}=\frac{3}{1-\frac{252000}{476000}+\frac{2\times 39000}{476000}}=\frac{3}{0.6345}=4.73.\text{ (Fr. and Eng.)}$$

Hence, *in gunboats of the "Aspic" type a small change in any of the weights on board implies a change of the same sign in the displacement* 4.73 *times greater, provided the same maximum speed and coal endurance are to be maintained.*

V.

CURVES OF SPEED AND POWER.

By Assistant Engineer R. S. Griffin, U. S. N.

The speed curves on the following pages, giving the speed and corresponding power of various ships, are intended to show the comparative performances of similar ships, each brought to a common displacement according to Froude's Law of Comparisons, and also the power required to propel ships of the assumed displacements at different speeds.

According to Froude's law, if two ships have the same coefficient of fineness, same water-lines, &c., but have dimensions whose ratio is n, then for speeds S_1, S_2, S_3 of one with resistances R_1, R_2, R_3, the "corresponding speeds" of the other will be $S_1\sqrt{n}$, $S_2\sqrt{n}$, $S_3\sqrt{n}$, for resistances n^3R_1, n^3R_2, n^3R_3.

In similar ships the cube of the ratio of dimensions is equal to the ratio of displacements. Therefore, n^3=ratio of displacements, and $\sqrt{n}$= sixth root of the same ratio.

Let R, S, D, and P represent the resistance, speed, displacement, and indicated horse-power for the large ship, and r, s, d, and p the corresponding quantities for the small one. Then

$$S=s\sqrt[6]{\frac{D}{d}} \qquad\qquad R=r\,\frac{D}{d}$$

Considering $P=R\times S$, we have

$$P=r\,s\,\sqrt[6]{\frac{D}{d}}\times\frac{D}{d},$$

or

$$P=p\,\sqrt[6]{\frac{D}{d}}\times\frac{D}{d}$$

As an example, take the Iris, bring her up to 5,000 tons, and find corresponding speed and power.

$$\begin{array}{lll}
D=5000 & \log 3.69897 & \\
d=3290 & \log 3.51720 & \\
\hline
n^3=\frac{D}{d} & \log 0.18177 & \\
\sqrt{n}=\sqrt[6]{\frac{D}{d}} & \log 0.03029 & \log 0.03029 \\
p=7556 & \log 3.87829 & \\
\hline
s=18.587 & & \log 1.26921 \\
P=12313 & \log 4.09035 & \\
\hline
S=19.93 & & \log 1.29950
\end{array}$$

NOTE.—This paragraph should have been placed at the end of CONTRACTORS' TRIAL. *

In other words, the "corresponding speed" of a vessel similar to the Iris, but of 5,000 tons displacement, is 19.93 knots, with 12313 indicated horse-power.

The speed shown by the curves represents the actual speed attained only when the displacement of the ship on trial was that for which the curve is constructed. This is approximately correct for the Howe and the Umbria on the 10,000-ton, and for the Imperieuse on the 7,500-ton curve, the great difference in the respective curves of the Howe and Umbria at high speeds being probably due to the ratio of length to beam, which is 4.78 for the former and 8.70 for the latter.

The data for the British naval ships have been taken from the records of progressive trials wherever available, and from contractors' and commissioning trials; the speed in nearly all cases being that made on the measured mile. For the Dolphin, the speed and power used were the mean results for three hours, and for the Vandalia and Swatara, the means for eight hours, the latter using four-fifths boiler power.

The data for the merchant steamers, with the exception of those for the Rotomahana and Charles Quint, which are from the report of Passed Assistant Engineer Tobin, U. S. Navy, are from the Mechanical Engineer.

The following are the regulations governing the steam trials of British naval vessels, from which the data used in constructing these curves were obtained:

PRELIMINARY TRIAL.

On the completion of new machinery by contractors, or of repairs, or in preparation for any full-power trial whatever, preliminary trials under steam may be made either at moorings, or alongside docks, or under way, as often as necessary to satisfy those who are responsible for the full-power trials that everything is in proper working order and fit for official trials.

Care is to be taken that the engines are never worked so as to produce an injurious effect upon the ship, &c.

During these four-hour trials the ship is occasionally run over the measured mile, and the speed, revolutions, &c., noted on each run. The speed for the four-hour continuous run is then arrived at by comparing these results with the total number of revolutions made during the trial, in connection with the other methods common to navigation.

CONTRACTORS' TRIAL.

Made to ascertain whether the engines develop the power required by specifications, and whether everything is in proper working condition. The machinery is in charge of the contractors, but an engineer officer from the dock-yard and the chief inspector of machinery of the reserve are present, and are responsible for the conduct of the trial according to the terms of the specifications. The length of these trials is generally four hours, and the vessel is usually brought to her load displacement by the addition of water ballast in the double bottom compartments. The trial is not to be considered complete until the following conditions have been carried out:

(1) A run of at least one hour with the expansion valves in full gear, or, if not fitted with expansion valves, with the slides linked up, and shorter runs at lower grades of expansion, in order to test the arrangement for working expansively.

(2) A trial of one or two hours at full speed, using jet injection.

(3) Stopping, starting, and reversing engines from full speed.

Stokers from the steam reserve are used unless the contractors prefer to use their own men. The coal is that specially ordered by the Admiralty for steam trials, and is provided by the contractors.

COMMISSIONING TRIAL.

Made as soon as convenient after going in commission, to ascertain what power should be developed by the engines, and what speed made under the normal conditions of service. The indicated horse-power is expected to approach that obtained on the contractors' trial. All weights are supposed to be on board, but in case some are not, mention of the fact must be made in the report.

The trial must continue for at least three hours, during which time the ship may be put on the measured mile, if considered desirable.

The stokers are from the steam reserve, and the coal is that specially ordered for steam trials, if it is believed that that in the ship's bunkers has deteriorated.

SPECIAL MEASURED MILE TRIAL.

Four runs at full power, four at half power, and four at any smaller proportion of power, are made on the mile,* each series being made while the tide is running in the same direction, and the mean of the speeds and powers for each series taken as the result.

During the intervals between the runs the ship is taken well away from the mile so as to insure the attainment of the regular speed on the next run, and the engines must be kept continuously working to their utmost, both during the interval and the run. Before commencing the trial the speed is to be regulated so that the steam pressure may be maintained at a maximum until the whole of the runs are completed. *Steam is not to be even partially shut off while off the course, in order to secure higher results while on it.* Should any irregularity occur during a run, rendering the result of that run untrustworthy, it may be eliminated and another made on the same tide substituted. The trial should not be made when the force of the wind exceeds 3.

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* The measured mile course is buoyed, and at right angles to the ranges indicated by the stakes on shore at the extremities of the course.

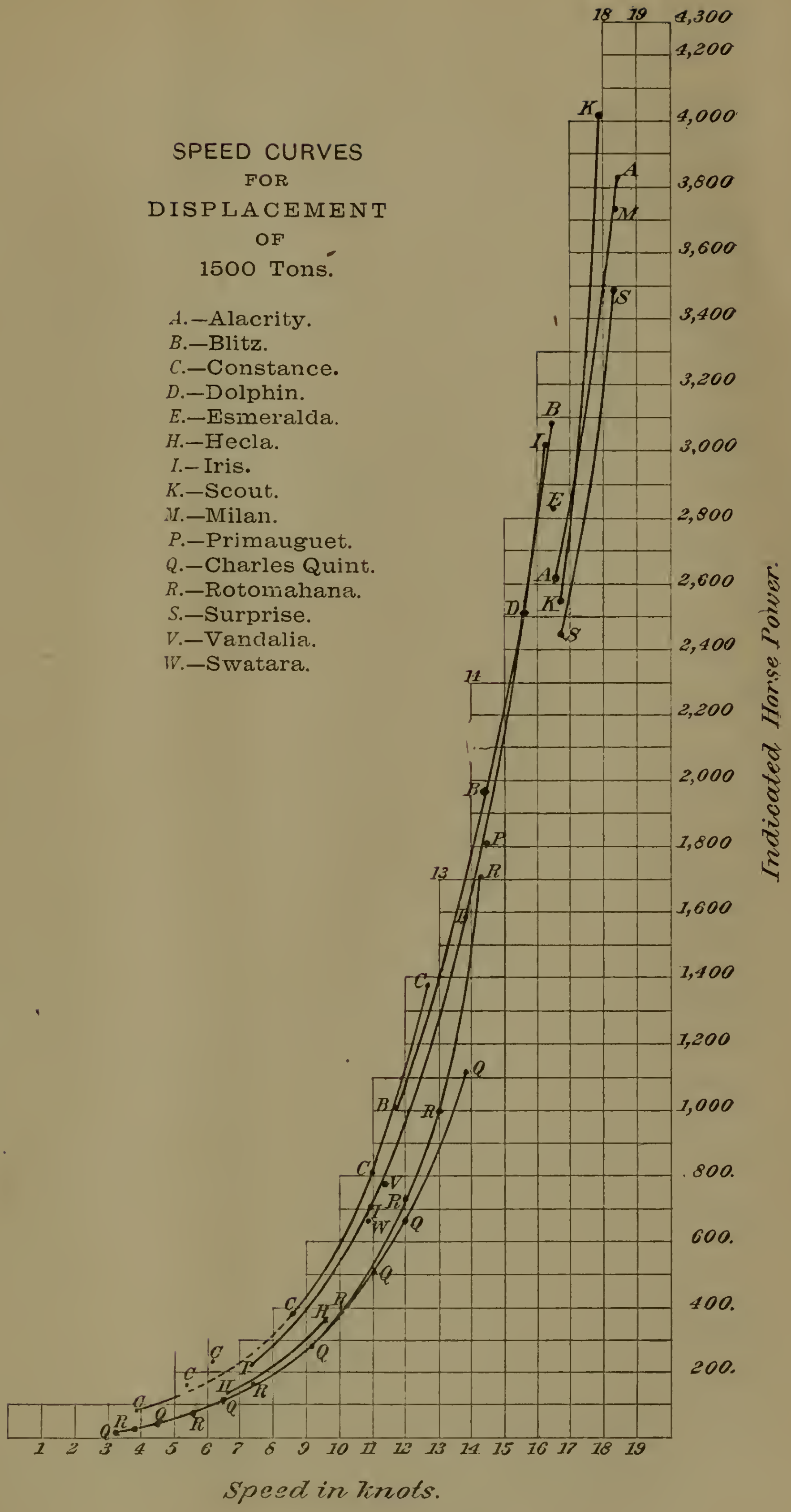
The stokers are from the reserve, and the coal is that specially ordered for steam trials.

Indicator diagrams are taken on all these trials by a staff from the dock-yard under the supervision of the chief engineer of the yard, who is responsible that the diagrams are properly taken, accurately worked up, and contain all necessary data, as well as for the correctness of the indicators, which are tested once a month in the presence of an engineer officer deputed by the chief inspector of machinery. The diagrams are taken half hourly, except on the measured mile trials, when they are taken once a run. In all cases the diagrams accompany the report of the trial, which is transmitted to the Admiralty through the superintendent of the dock-yard.

The following table gives the principal dimensions of the vessels used in constructing the speed curves:

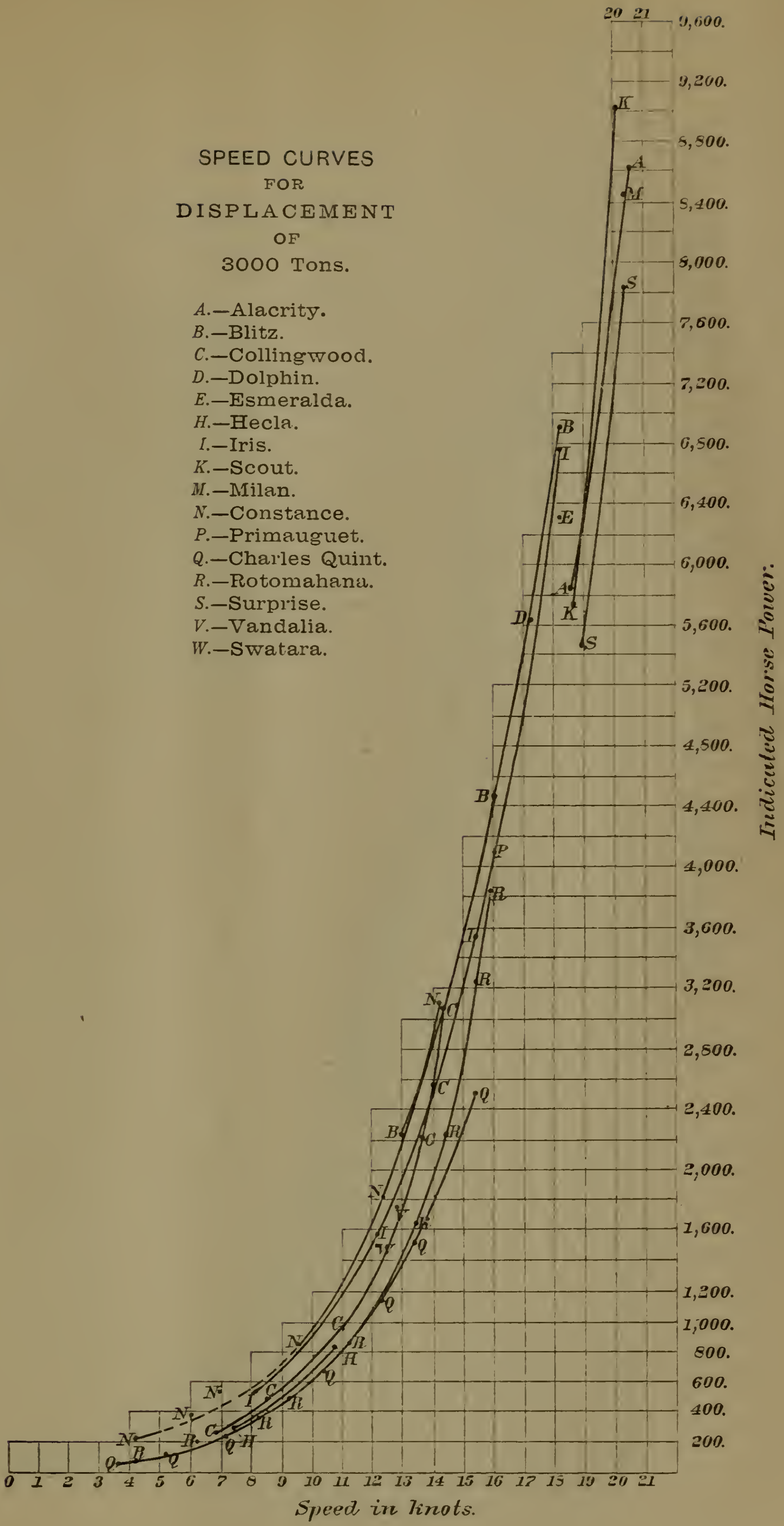
Vessels.	Length between perpendiculars.	Beam.	Mean load draught.	Load displacement.	Displacement on trial.	Ratio of length to beam.
Agamemnon	280	66	23½	8, 510	8, 510	4. 24
Alacrity	250	32½	13	1, 400	1, 274	7. 70
Alexandra	325	63⅔	26¼	9, 490	9, 432	5. 10
Blitz	245	$32\frac{7}{12}$	13¼	1, 382	1, 382	7. 52
Collingwood	325	68	25¾	9, 150	8, 060	4. 78
Constance	225	44½	$18\frac{5}{12}$	2, 380	2, 380	5. 00
Conqueror	270	58	23	6, 200	6, 000	4. 65
Dandolo	339½	64¾	28¾	11, 225	10, 600	5. 24
Dévastation (French)	311½	71	$24\frac{1}{12}$	9, 639	9, 639	4. 38
Dolphin	240	32	14¼	1, 500	1, 300	7. 5
Dreadnought	320	63⅚	26½	10, 820	10, 820	5. 01
Edinburgh	325	68	25¾	9, 150	8, 760	4. 78
Esmeralda	270	42	18½	2, 900	2, 900	6. 43
Hecla	$391\frac{7}{12}$	38¾	23	6, 400	5, 760	10. 10
Howe	325	68	26¾	9, 600	9, 600	4. 78
Impérieuse	315	62	25	7, 390	7, 390	5. 16
Iris	300	46	19½	3, 730	3, 290	6. 52
Milan	303	32⅚	12¾	1, 550	1, 550	9. 23
Primauguet	286⅚	$37\frac{5}{12}$	18½	2, 236	2, 236	7. 65
Riachuelo	305	52	19⅔	5, 790	5, 677	5. 86
Scout	220	34	13½	1, 430	1, 285	6. 42
Surprise	250	32½	13	1, 420	1, 320	7. 7
Swatara	216	37	16½	1, 900	1, 900	5. 84
Vandalia	216	39	17¼	2, 100	2, 100	5. 54
Alaska	474½	50½	26	9, 500	*9, 500	9. 35
Arizona	450	45½	26	9, 000	*9, 000	9. 90
Britannic	450	45⅙	$23\frac{7}{12}$	8, 500	*8, 500	9. 96
Charles Quint	323	33¾	14⅚	2, 478	2, 478	9. 57
City of Rome	546	52¼	26	13, 300	*13, 300	10. 45
Etruria	500	57½	26½	13, 300	*13, 300	8. 70
Gallia	430	44	25	8, 600	6, 125 *8, 200	9. 77
Normandie	460	50	24½	10, 050	7, 656	9. 20
Oregon	500	54	26½	12, 500	*12, 500	9. 26
Rotomahana	285	35⅙	15	2, 425	2, 425	8. 15
Servia	515	52½	26½	12, 300	12, 450	9. 90
Umbria	500	57½	26½	13, 300	9, 860	8. 70

* Sea trip.

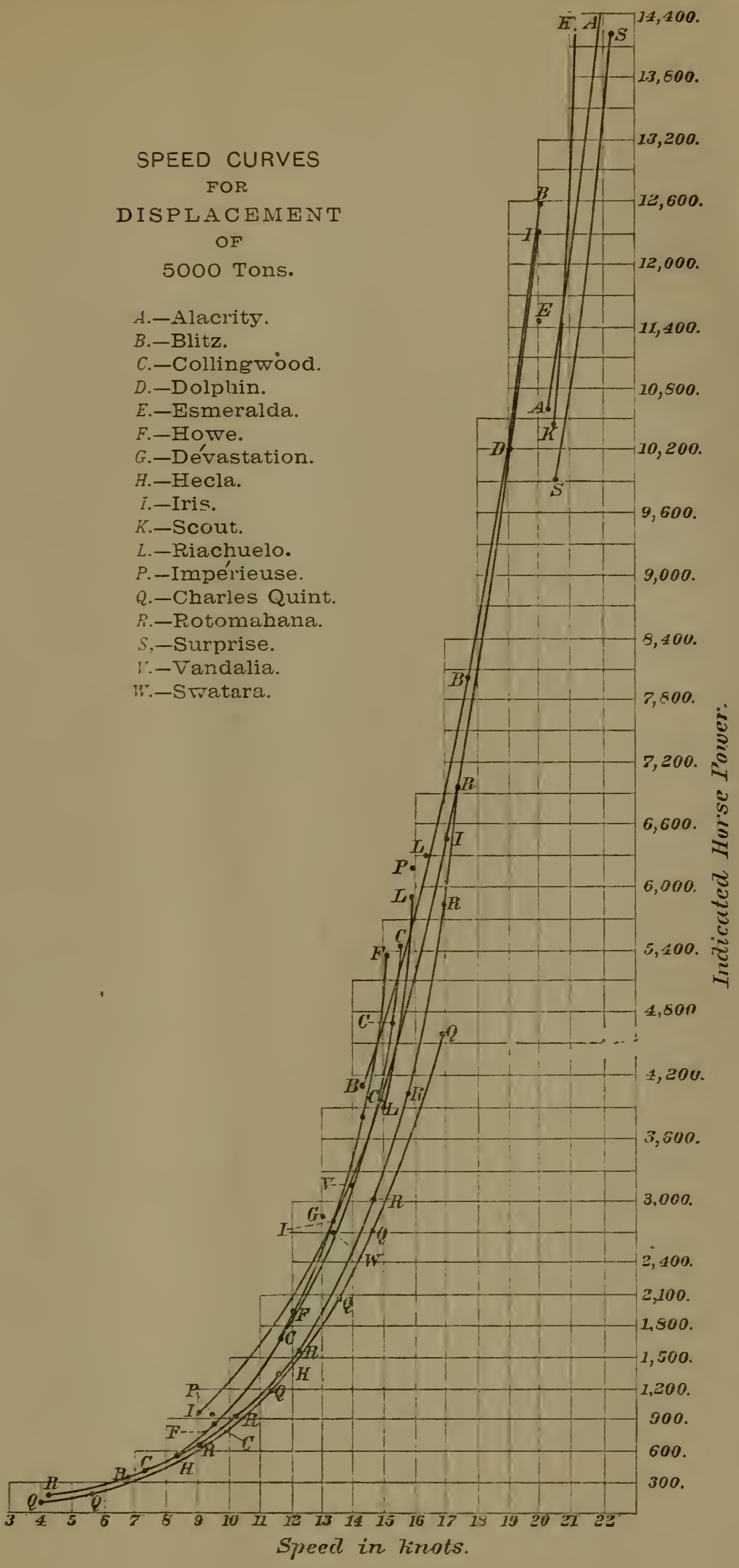


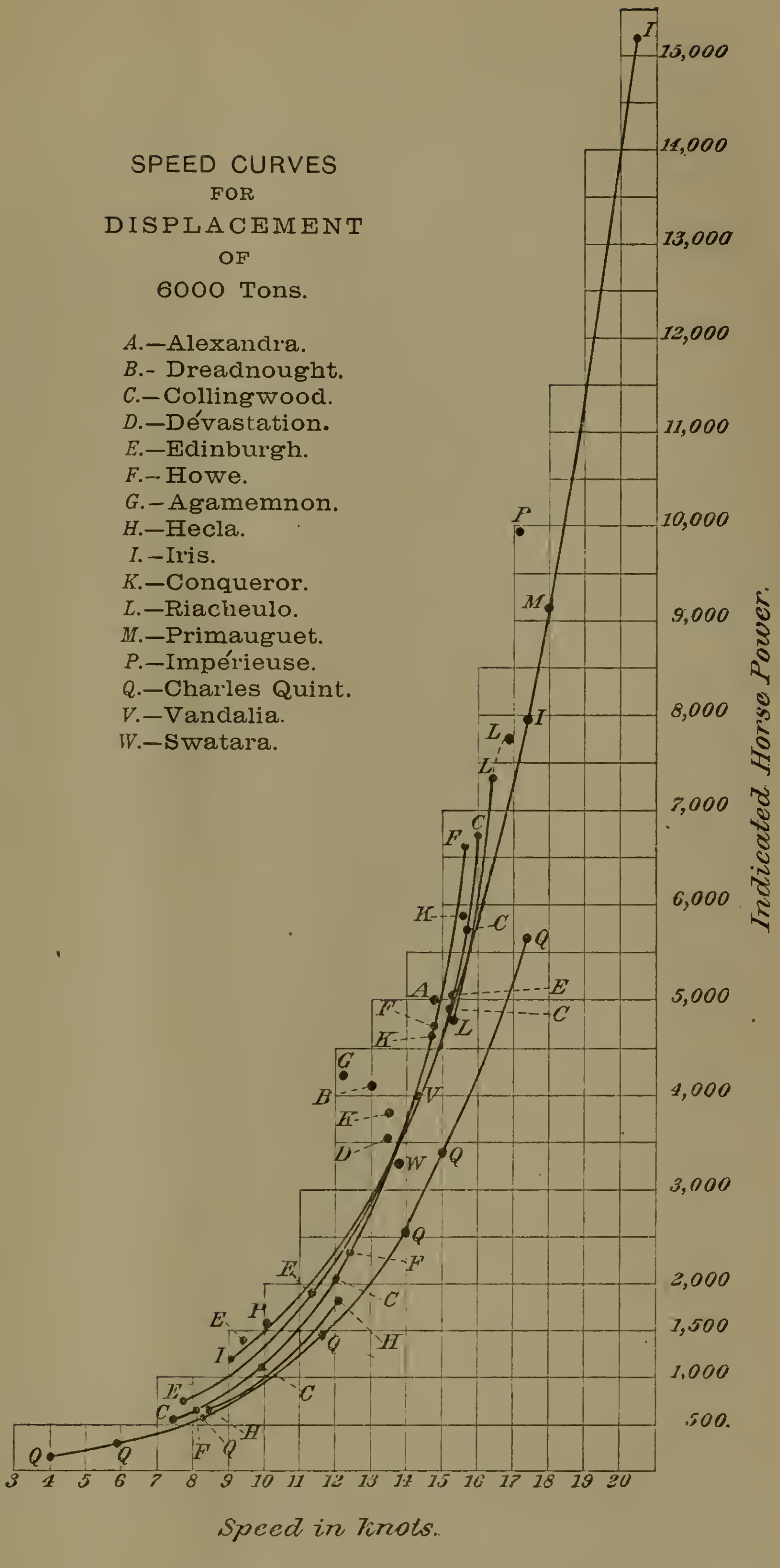
SPEED CURVES
FOR
DISPLACEMENT
OF
1500 Tons.

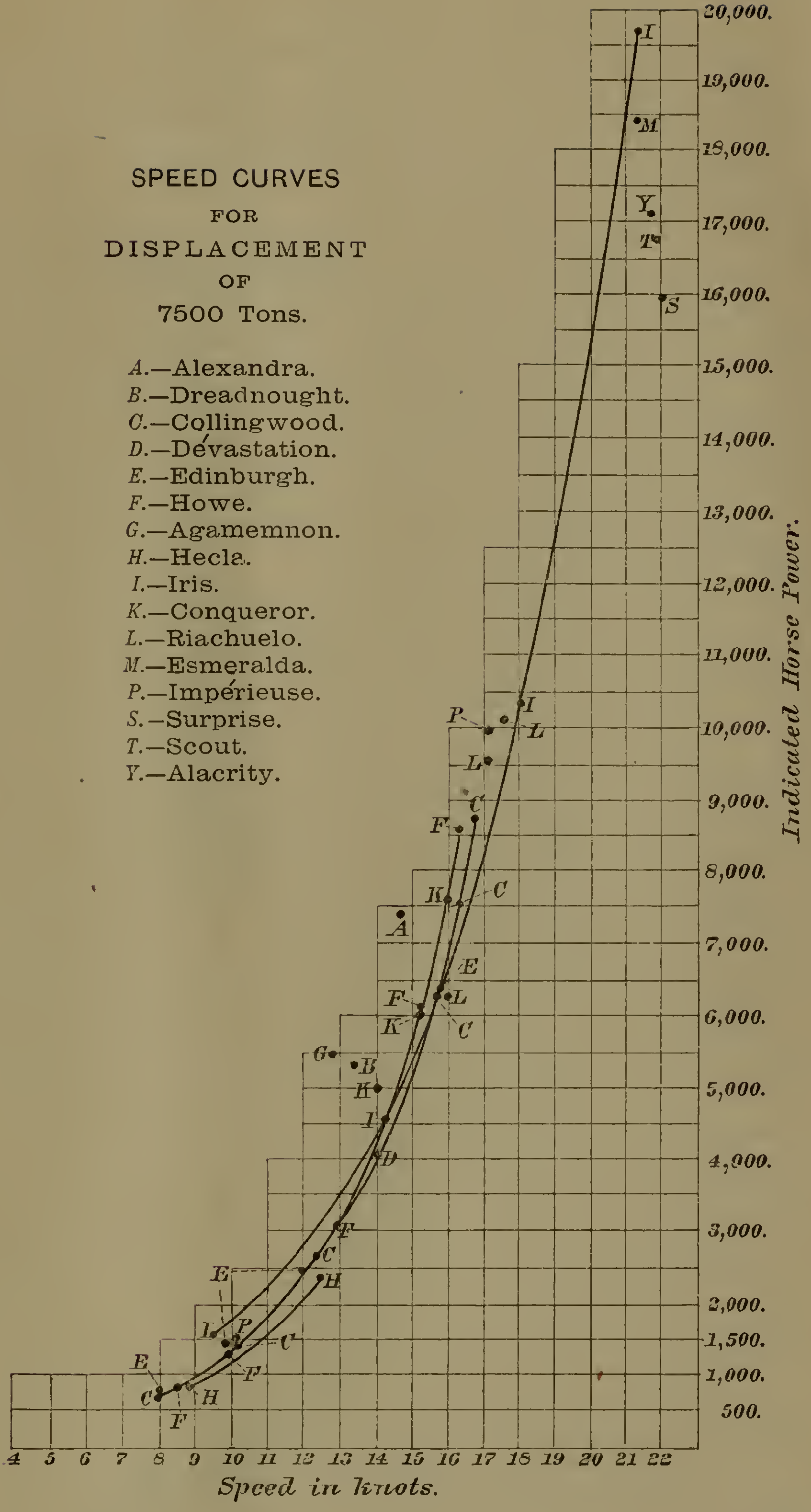
- *A.*—Alacrity.
- *B.*—Blitz.
- *C.*—Constance.
- *D.*—Dolphin.
- *E.*—Esmeralda.
- *H.*—Hecla.
- *I.*—Iris.
- *K.*—Scout.
- *M.*—Milan.
- *P.*—Primauguet.
- *Q.*—Charles Quint.
- *R.*—Rotomahana.
- *S.*—Surprise.
- *V.*—Vandalia.
- *W.*—Swatara.



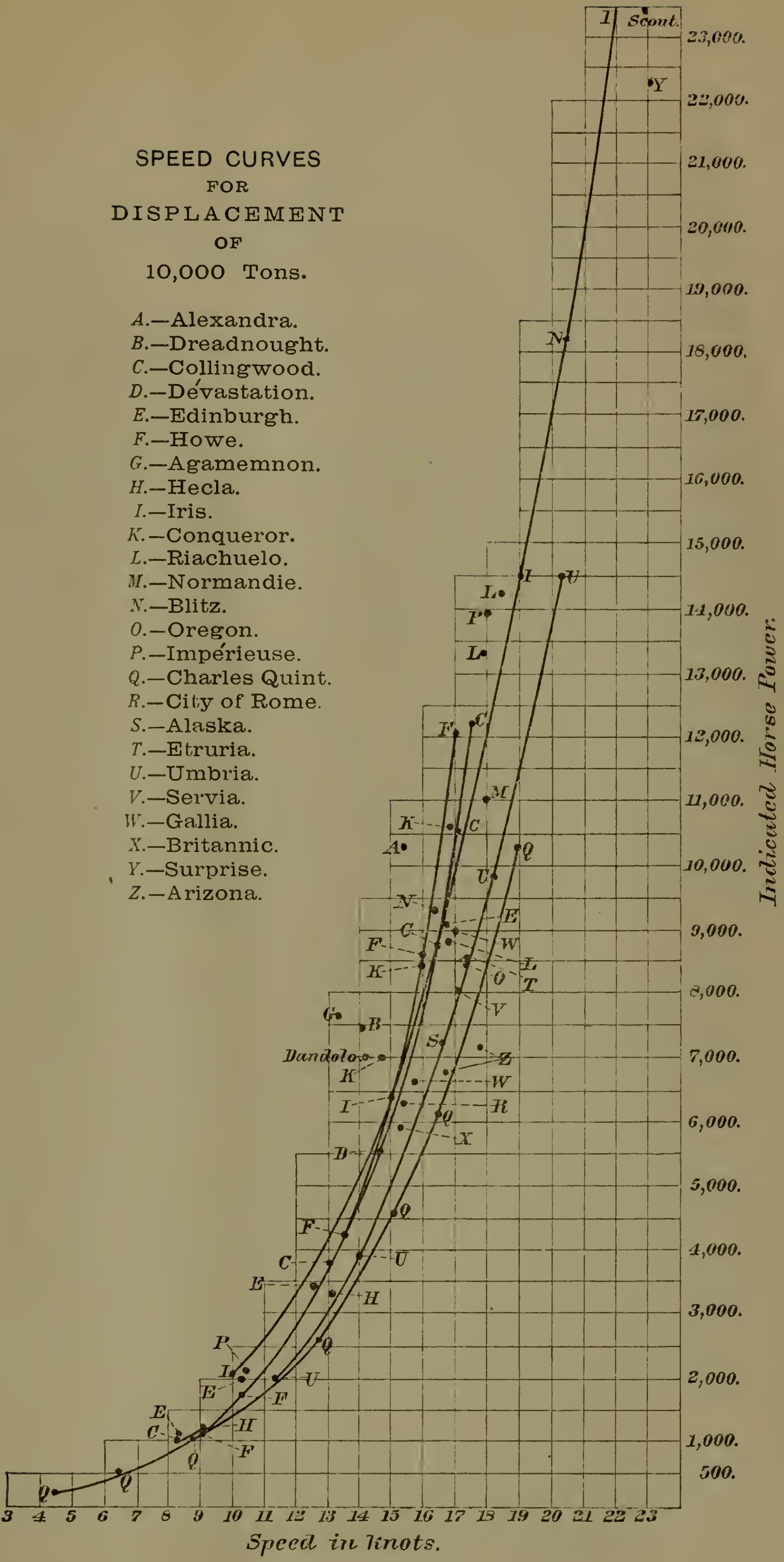
SPEED CURVES
FOR
DISPLACEMENT
OF
3000 Tons.


SPEED CURVES
FOR
DISPLACEMENT
OF
5000 Tons.


SPEED CURVES
FOR
DISPLACEMENT
OF
6000 Tons.
A.—Alexandra.
B.- Dreadnought.
C.—Collingwood.
D.—Dévastation.
E.—Edinburgh.
F.—Howe.
G.—Agamemnon.
H.—Hecla.
I.—Iris.
K.—Conqueror.
L.—Riacheulo.
M.—Primauguet.
P.—Impérieuse.
Q.—Charles Quint.
V.—Vandalia.
W.—Swatara.
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,500
1,000
500.
Indicated Horse Power.
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Speed in knots.



SPEED CURVES
FOR
DISPLACEMENT
OF
7500 Tons.



VI.

LIQUID FUEL.

By Assistant Engineer R. S. GRIFFIN, U. S. Navy.

The success attending the use of naphtha as a substitute for coal on some of the Russian railways, and on the steamers engaged in the oil trade of the Caspian and Volga, together with the outlet for Russian naphtha made by the railway from Baku to Tiflis and Poti, has induced many attempts in Europe to successfully burn "liquid fuel" in the furnaces of sea-going steamers. Previously to 1883, when the railway was opened, the naphtha of Baku could only reach the Black Sea through the interior of Russia, being shipped in barrels from Baku to Astrakhan, thence by light-draught cistern steamers to Tzaritsin, whence it was transported by rail. Owing to the physical difficulties to be overcome, the railway from Baku cannot transport more than one-fourth the annual yield of naphtha, and a pipe line from Baku to Batum is now contemplated, which, if completed, will make naphtha so cheap in the Black Sea that a coal-burning steamer will not be able to compete with one burning liquid fuel.

The advantages claimed for liquid fuel are increased evaporation over that obtained from coal, and consequently a less weight of boilers for the same power; reduction of one-third the number of firemen, and doing away with all coal-heavers; cleanliness—no smoke, no refuse, no hauling of fires; facility of raising steam rapidly, and of having the pressure at all times under control; reduced bulk and weight for the same length of steaming, which should specially commend it for use on torpedo-boats; less wear and tear of boilers. It is easily stowed, and there is no loss from firing, opening furnace doors, and cleaning fires.

Against these must be placed the great precaution necessary in stowing it; the danger from spontaneous combustion, due to leakage; the care necessary with lights, owing to the inflammable nature of the gas given off at all temperatures, and the almost certain loss, in case of fire, of a steamer using it.

Chief Engineer N. B. Clark, U. S. Navy, in the Journal of the Franklin Institute for May, 1884, urges the employment of petroleum as "emergency" fuel in war steamers, and says that, if the same precautions be taken, there should be no more danger from its presence on board than there is from gunpowder. He advises that the oil be stowed in the water-bottom, which should be provided with ventilating tubes having a discharge overboard above the water-line; and that, inasmuch as one-third the present fire-room force are "emergency" men, their services could be dispensed with if "emergency" fuel be employed.

Sir E. J. Reed, in the recent debate on the British navy estimates, said that he thought it probable that in a few years the navy would be burning liquid fuel.

The principle of all liquid-fuel burners is the same, the fuel being supplied by one pipe, and the spraying agent by another, both meeting at a narrow opening, the fuel being thrown into the furnace in the form of very fine spray. Figs. 1 and 2 represent Artemeff's and Karapetoff's burners used on some of the Russian railways and Caspian steamers. In Fig. 1 A is the naphtha and B the steam pipe, C a slot through which the naphtha is sprayed, and D cocks for regulating the supply of either naphtha or steam. The burner is, besides, provided with a blow-through cock for keeping the naphtha passage clear of sediment, the fuel used being a refuse from the first distillation of naphtha, called *astatki*. In Fig. 2, besides the passage for fuel and steam, there is a third for air, the introduction of which has proved very successful in helping to consume the smoke. This burner is so placed at the furnace front that it throws a flame down upon a refractory brick bottom, which, attaining a high temperature, helps consume any small particles of fuel which may reach it. The supply of fuel is regulated by the slide S.

Exhaustive experiments were made at Marseilles last year by the Fraissinet Company, using a marine return tubular boiler set up in their shops, and afterward on board the S. S. Aude. The only alterations made were the removal of the grates, the division of the furnace by a sheet-iron plate, covered with fire-brick, running the full length of the furnace, and the introduction of a brick arch under the crown-sheet; the only openings in the furnace front were for the burners and peep-holes. The burner used is the invention of M. d'Allest, and consists of two conical tubes, one within the other, liquid fuel being supplied to the internal, and steam to the external one; the whole apparatus being within a bell-mouth nozzle open to the atmosphere, by which means a current of air is induced which materially assists combustion. The trials with this arrangement of furnace and burner were quite satisfactory; the pressure being maintained without any difficulty, and at all times under perfect control. The necessity, however, of allowing more direct heat to inpinge on the boiler was manifest, and in place of the brick arch a gas retort perforated with a number of small holes was introduced. This is shown in Figs. 5 and 6 in longitudinal and enlarged cross-section. The spray of naphtha is directed into the retort, which soon attains a red heat, and thus assists in burning the fuel. The gases escape by the openings B, lick the top and sides of the furnace, overlap one another, and so have their velocity diminished. In the end of the retort there are a number of iron tubes, C, passing through it from the air-pit to the combustion-chamber. By opening the door D, a strong current of air is induced, which, passing under the retort and through the tubes, is quickly heated, and helps consume any gas which may have escaped from the retort without having imparted its useful effect. It is found advantageous to admit only a small quantity of air through the burner and the greater part by the air-pit door.

In all these experiments it was shown that the hot gases attain a very high velocity, and that consequently there is considerable loss of heat by the chimney, the temperature there being very high, especially with forced draft. Even with natural draft the speed of the gases is not sensibly diminished; their volume is less, but instead of filling the whole nest of tubes, they escape by a limited number, and reach the uptake at about the same temperature as when forced draft is used, carrying a large proportion of the heat up the chimney. To remedy this, and to utilize as far as possible the heat of combustion, the Fraissinet Company designed the boiler shown in Fig. 5, the principal features of which, besides the retort already described, are a low combustion-chamber, and two nests of tubes, one above the other, connected at the front of the boiler by a brick-lined smoke-box. It is especially claimed for this boiler that it gives a largely increased amount of heating surface, and occupies very little more space than the ordinary boiler, besides reducing the speed of the gases and utilizing more of the heat of combustion.

It early became apparent in these experiments that the expenditure of steam for the spraying apparatus largely diminished the apparent evaporative efficiency of the fuel, and that the salting of the boilers on long sea voyages would be a serious obstacle to the employment of such a burner. Accordingly it was determined to substitute air for steam, and to modify the burner. It was found that the spraying of the fuel did not require a very high velocity in the spraying fluid, so this point was made use of in constructing the air-blast burner, the speed of the blast being diminished, and all the air required for combustion, as well as that for spraying, being admitted through the burner, and mixed as intimately as possible with the combustible, by which means the efficiency was increased in a marked degree. This burner is shown in Figs. 3 and 4. The principle is the same as that of the steam-blast burner: Air, admitted by suitable means, passes through A into the tube B, and thence into the furnace in the form of a cylindrical jet; at the orifice it meets the liquid fuel, which enters at E and is carried into the furnace between the two streams of air. The fuel, instead of being a continuous ring, is divided into four parts, thus permitting a thorough mixture of air with it and insuring perfect spraying. The variation in the stream of fuel, and consequently in the quantity admitted to the furnace, is regulated by the hand-wheel G, which moves the central nozzle in or out. The cover is easily removed for examination or cleaning of the burner.

While these experiments were very satisfactory, the impossibility of procuring the fuel in sufficient quantity, at reasonable cost, to justify the expenditure necessary in making the alterations in the boilers, has thus far prevented the substitution of liquid fuel for coal. Besides, in the event of war closing the Dardanelles, the supply of fuel, which in these experiments was Russian *astatki*, would be completely cut off.

The French Government is to test M. d'Allest's apparatus on one of their torpedo-boats, the question of cost being of minor importance compared with the advantages to be derived should the test prove satisfactory.

Liquid fuel has also been successfully used on board the Tamesi, a steamer plying between Bordeaux and Senegal, giving economic results warranting its continued use.

In Great Britain the first steamer in which liquid fuel was used was the Himalaya, now the Marahu, of 800 tons displacement, with compound engines of 500 I. H. P. The boilers have each three furnaces, with fire-brick lining, on the principle of Siemen's regenerative system, and a brick arch or baffle with an aperture through which the heated gasses pass to the tubes. The apparatus for burning the fuel consists of a coiled iron pipe placed in the combustion chamber, one end of the pipe leading to the steam space of the boiler the other to the furnace mouth, the object of this part of the arrangement being to superheat the steam for spraying the oil, the nozzle of the oil pipe being within the steam pipe. There is, besides, an automatic starting arrangement, by means of which oil is supplied to the furnaces while raising steam. The entire apparatus is so placed that it can be easily removed in case it becomes necessary to burn coal. The Himalaya formerly burned 10 tons of coal a day, and carried 240 tons in her bunkers; she now burns 4½ tons of oil a day, and carries 110 tons of it. The rest of the fuel space is given up to cargo.

This apparatus (Tarbutt's) has recently been fitted on board a steamer built for the Black Sea trade, having her water-ballast tanks subdivided and made available for oil stowage.

Another steamer, the Cobden, engaged in the Mediterranean trade, has made a number of voyages, burning creosote in her furnaces, and no complaints have been made by those using the fuel. Several attempts have been made at Portsmouth, England, to burn creosote according to Colonel Sadler's method as applied in the Cobden, but thus far the trials have not been attended with great success. The attempt to burn liquid fuel in torpedo-boat No. 22 was so unsatisfactory that it was abandoned.

In the United States there are three steamers belonging to the Southern Pacific Company, the Solano, Piedmont, and Thoroughfare, that burn liquid fuel. They are all ferry steamers fitted with beam engines, and use the same boilers that they did when burning coal. The alterations made were the introduction of a fire-brick baffle, the covering of the grates with fire-brick, and making the furnace air-tight, a door being cut below the burners to regulate the supply of air. The burners are of very simple construction, consisting of a three-fourth-inch oil pipe, surrounding a one-fourth-inch steam pipe, terminating in a horizontal opening one-sixteenth of an inch wide, and $1\frac{7}{8}$ inches long, the flame being directed upon the fire-brick covering the grate. In lighting fires, great care is necessary that the oil be lighted as soon as it is admitted to the furnace, especially if the furnace has previously been warmed up enough to generate a gas from the oil not lighted. When shutting off, the same care is necessary to see that the flow of oil has ceased before closing the steam jet.

These steamers keep up steam at all times, but when lying in the slip the oil is shut off and the furnaces closed perfectly air-tight. The same number of furnaces are used with the oil as with coal, the same speed maintained, and no trouble is met with from deposit of carbon on the burners, nor is any annoyance or inconvenience occasioned by its use. The space for stowing is about one-third that for coal doing the same work, while the expense and time of stowing are correspondingly reduced, the oil being pumped from tank cars into the steamer's tanks, consuming about forty minutes a day against two hours before required for coaling. The tanks are at a convenient distance from the boilers, and are so connected that all may be filled or emptied at the same time. The oil burned is a residue, known as "Fuel-oil," purchased from the Pacific Coast Oil Refining Company, and if not utilized in this way would be thrown away. The saving effected by its use has been about 42 per cent. on the Solano and Thoroughfare, and 7 per cent. on the Piedmont. The difference is due partly to the difference in the service of the steamers, and partly to the kind of boilers, which are of the locomotive type on the Solano, externally fired on the Thoroughfare, and flue on the Piedmont. The Piedmont is running almost constantly, while the others make very short trips, about seven or eight minutes each. The saving on the Piedmont is due entirely to the reducing of the fire-room force, a saving in wages only.

There are now more than three hundred steamers on the Caspian, and five hundred on the Volga, which burn liquid fuel in their furnaces. Of this number, some are steamers from 250 to 350 feet long, with engines developing from 1,500 to 4,000 indicated horse-power.

Several steamers have recently been built for the special purpose of transporting petroleum in bulk. The largest of these is the Sveat; built in Sweden for the Russian Black Sea Steam Navigation Company, to ply between Batoum and Odessa. She is 286 feet long, $36\frac{1}{2}$ beam, and 18 draught, with a displacement of 1,900 tons; her engines are of ~~1,900~~ 1100 I. H. P., giving her a speed of $11\frac{1}{2}$ knots. She burns coal, but her bunkers have been constructed with a view to holding naphtha, in case it is decided to burn liquid fuel instead of coal.

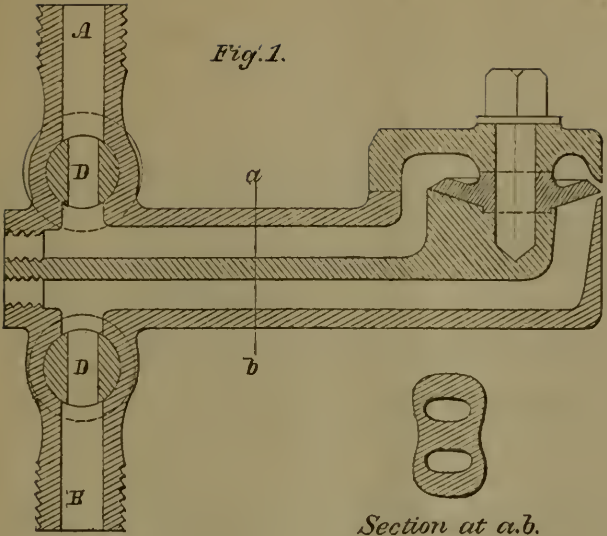
The midship portion of the ship is taken up with oil cisterns, sixteen in number, arranged in two rows; outside of each row there is a passage, and between the under side of the lower row and the inner bottom of the steamer there is a space to permit of the examination of the cisterns at all times. All are connected with a common pipe leading to the pumping engines, and each has a ventilating tube leading to the upper deck. To prevent accumulation of gases in the passages, sixteen large ventilating tubes are provided, eight of which serve to introduce air, and eight for the escape of gas. Besides these oil cisterns, there are others for water ballast, and abaft the oil cisterns are safety cisterns, for the express purpose of separating the oil from the machinery. These are made very strong, and are intended to be filled with water. The cost of the Sveat was £37,500.

The United States bark Crusader, and the German ship Andromeda, have also been fitted up to transport petroleum in bulk, the former having made one or two voyages.

The evaporative efficiency of different kinds of liquid fuel is given in the following list:

	Pounds water evaporated at 212° F., per pound of fuel.
Petroleum, Brooklyn navy-yard, 1866	13.44
Petroleum, Woolwich, 1866–'67	13.66
Creosote, Sadler's experiments, 1885	13.00
Scotch shale oil, 1885	15.50
Astatki, Fraissinet Company, on shore, 1885	15.29
Astatki, Fraissinet Company, Aude, 1885	14.10
Astatki, Grazi-Tzaritzin Railway, 1884	14.00

Fig. 1.



Section at a.b.

Fig. 2.

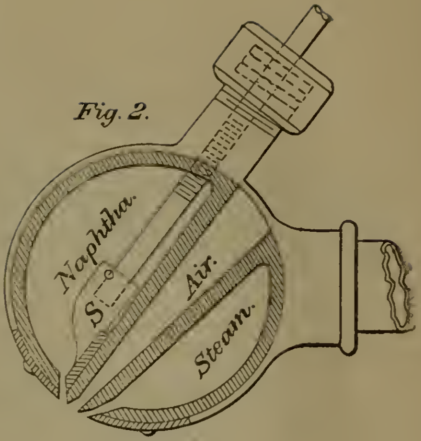


Fig. 3.

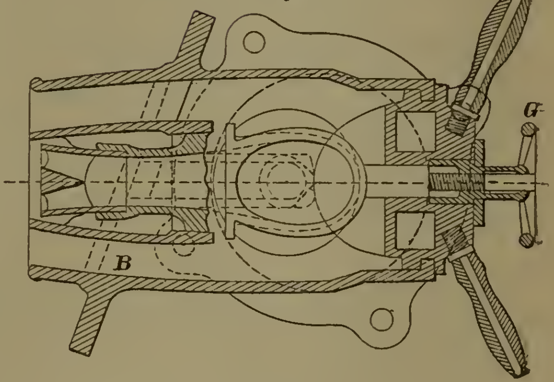


Fig. 5.

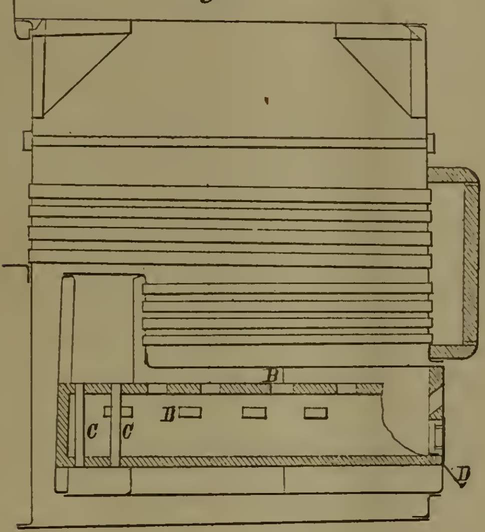


Fig. 4.

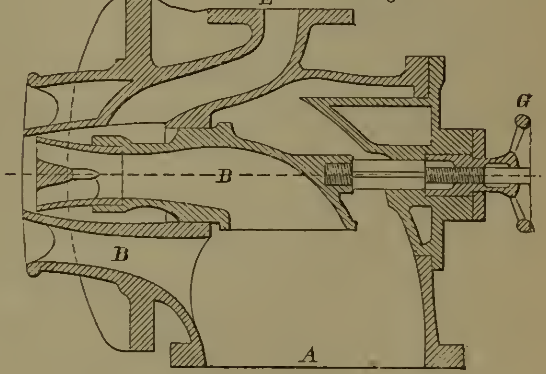
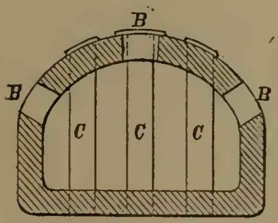


Fig. 6.



VII.

REPORT ON THE INCLINING AND ARTIFICIAL ROLLING OF THE U. S. S. TENNESSEE, TO DETERMINE THE STILL-WATER PERIOD AND RATE OF EXTINCTION OF OSCILLATION.

By Assistant Naval Constructor L. NIXON, U. S. Navy.

In obedience to the Department's order of October 14, 1885, I have the honor to submit the following report of the inclining and artificial rolling of the U. S. S. Tennessee, in the North River, at the foot of Ninety-sixth street, New York City, November 4 and 5, 1885.

Two pendulums were used in these experiments. One consisted of an ordinary plumb-bob suspended by means of a fine wire, with a ring at its upper end, which was placed over a nail filed to form a knife edge. This was set up in the fore-hatch, and a horizontal athwartship batten was secured close to the wire just above the bob and 20 feet from the point of suspension.

The second pendulum was of special construction, as a pendulum of exceedingly short period was required. It consisted of a piece of one-sixteenth-inch steel plate, shaped as shown in Fig. 1, with a length from the knife edge to point of index of 30 inches. This was hung on a knife edge, fixed normally on a smooth board, painted white. A closely divided scale was drawn in India ink at a suitable radius from the knife edge. Thick curved pieces of lead were firmly secured to both sides of the sheet metal close to a point of suspension. This gave the pendulum a comparatively small moment of inertia combined with great directive force, thus securing a short period of oscillation. The pendulum was set up on shore when completed, and the period for a single swing from one side to the other was found to be .465 of a second.

The experiments will be described in the order in which they were made. The vessel was rolled on the morning of November 4, but owing to the wind, the results were not satisfactory. On the morning of November 5 the entire series of experiments was performed. The vessel was, as nearly as possible, in the same condition as when leaving port, with regard to the amount and location of the weights, and the security of those liable to shift. The bilges were perfectly dry, water-tanks completely full, boats, booms, tiller, and running rigging secured, sails bent, yards squared, and water at working level in the boilers. The vessel was anchored by the port anchor. The cable was up and down during the experiment, having been veered to 45 fathoms just before it began.

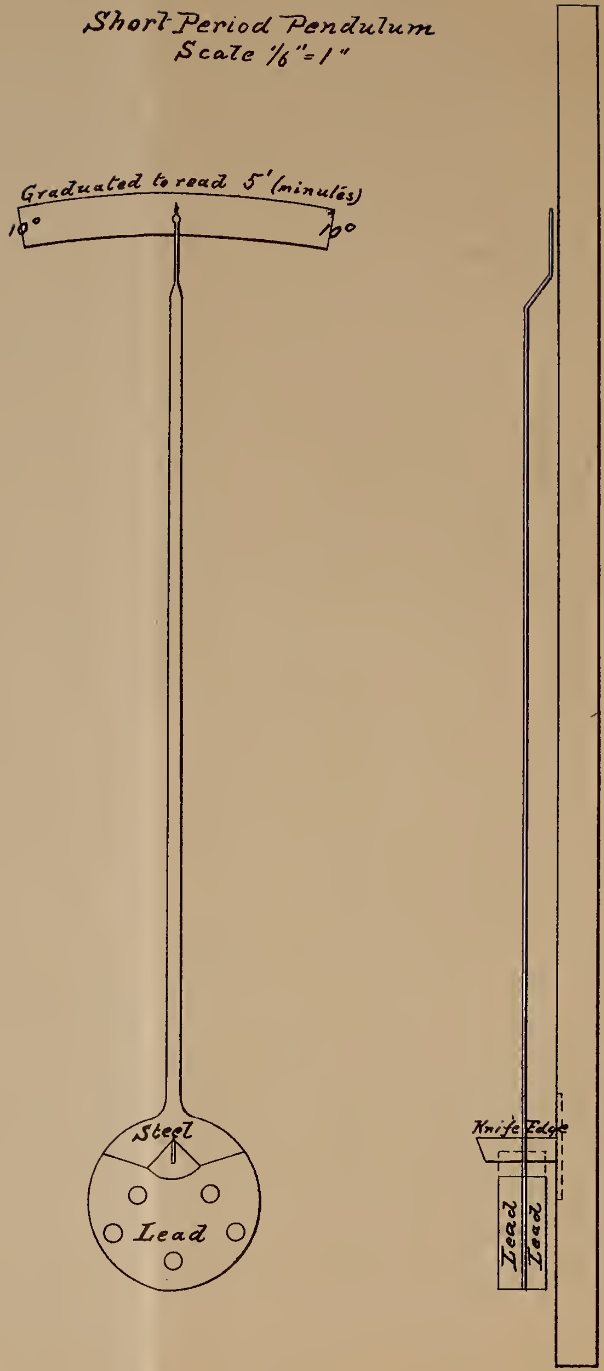
An initial rolling motion was given to the ship by running a portion of the crew, one hundred and thirteen men, in two lines across the clear spaces of the gun and spar decks. All men not running were sent below and made to sit down on the berth deck during the experiments. The motion of the men was so timed that they kept time with the motion of the ship, but were at the middle line running toward the high side when the vessel began her roll from the low side. A roll of 6 degrees was got up by running the men fifteen times across the decks, and 6½ degrees by running them twenty-five times, showing that 6½ degrees was about the maximum roll that could be obtained in this manner. The short period pendulum was set up on the berth deck at the middle line, and about 6 feet forward the mainmast, the knife-edge suspension being about 10 inches above the berth deck. Before beginning the experiment the men who were to run were made to sit down amidships, and the reading of the pendulum was taken. This gave the zero from which to reckon the angles of roll. When a roll of the required amplitude was obtained, the men were halted at the middle line and made to sit down, and the successive inclinations noted by the pendulum thereafter were read from the arc and recorded. Lieut. Samuel W. Very, attended near the pendulum and read and recorded the time at each extreme swing, the instant of reaching the extreme angle being passed from the pendulum.

The pendulum marked most satisfactorily and seems to be perfectly adapted for still-water rolling while its simplicity and cheapness leave nothing to be desired. Seven minutes covered the whole time of getting up and recording a series of rolls. Two series were observed with the water in the boilers at working level, and then the boilers were run full and two series observed.

For the inclining experiments both pendulums were used. The men were made to sit down amidships, and the point where the wire of the long pendulum cut the athwartship batten was marked on the batten, and the reading of the other pendulum was taken. Then all the guns of the starboard battery were run in 6 feet exactly, and the men again made to sit down amidships. The point where the wire of the long pendulum cut the batten, was then marked on the batten, and the arc recorded by the short pendulum was read. The starboard battery was then run out and secured, and the men again made to sit down amidships. Then the same was done with the port battery as had been done with the starboard. The distances marked on the batten were carefully measured and recorded.

As the tide had begun to run by the time this experiment was performed, it was deemed best to repeat the experiment at the time of the next slack water, and another experiment was accordingly made about

Fig. 1.



Short-Period Pendulum
Scale 1/6"=1"

7 p. m., when six guns in each gun-deck battery were run in 8 feet, the remaining guns of the battery being run in 6 feet as before.

The results were as follows:

Eight guns on the gun-deck, each weighing 4.82 tons, and two guns on the spar-deck, each weighing 4.95 tons, were run in 6 feet, giving a moment of 290.76 foot-tons, and this produced an inclination of 4.7 inches in 20 feet, while an angle of 1 degree 7½ minutes was shown by the short-period pendulum. This gave a metacentric height of 3.11 feet. In the second experiment six guns on gun-deck were run in 8 feet; two guns on gun-deck were run in 6 feet; two guns on spar-deck were run in 6 feet, giving a moment of 348.6 foot-tons, and this produced an inclination of 5.65 inches in 20 feet, giving a metacentric height of 3.11 feet.

The ship's draught was 19 feet 3 inches forward and 23 feet 9 inches aft, and to this draught the displacement is 4,760 tons. The center of buoyancy is 9.754 feet abaft the center of length between perpendiculars, and 7.964 feet below the water plane. The metacenter is 1.6214 feet above the water plane. The general distribution of weights in the vessel, and the position of the center of gravity are shown on the accompanying drawings of the vessel.

The successive angles of roll recorded in the rolling experiment were set off on equidistant ordinates, and the effects of a slight independent oscillation of small range, which the ship was performing in obedience to some slight surface undulation of the water and casual wind impulse, was eliminated. This led to the curves shown in Fig. 2, which represent the curves of extinction in the two cases of water in boilers at working level and boilers full.

These curves were drawn out on a very large scale and the differential equation of the curve assumed to be—

$$-\triangle\theta=a\theta+b\theta^2$$

a and b being constant for a particular ship; then, by an application of the method of least squares, the values of these constants were found.

The above equation was suggested by the late Mr. Froude, who was of the opinion that the total resistance consists of two parts, one varying as the (angular velocity)^2 and consisting mainly of the keel and frictional resistance, and another varying as the angular velocity, and represented chiefly by the surface disturbance, the effects of the former being shown in the above equation by the b coefficient, and of the latter by the a coefficient. The French authorities contend that the form of the equation is—

$$-\triangle\theta=b\theta^2$$

but on applying the method of least squares to this entirely independent set of observations, the a coefficient, instead of coming out zero, has a perfectly consistent value, furnishing an independent check on the already undoubted soundness of Mr. Froude's deductions. The results of the rolling are—

Condition.	*a*	*b*	Period.
Water at working level	.0548	.00144	6.533
Boilers full	.0323	.00714	6.40

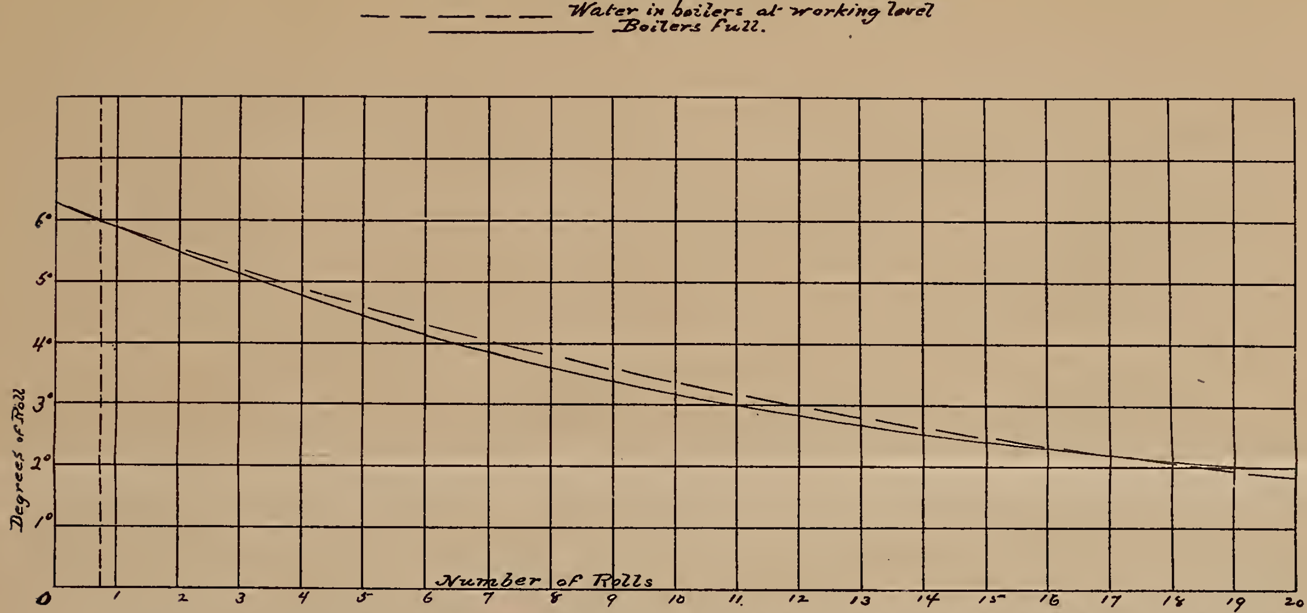
The Tennessee is noted as a very steady ship at sea, and it is thought that an analysis of her various features and a comparison of them with those of other ships will be of interest. When iron-clads were first advocated, an objection was raised against them that they would roll very heavily, as top-heaviness was then believed to be a cause of heavy rolling, while as a matter of fact, top-heaviness within proper limits, leads to easy motion. Where a vessel is heeled to a certain angle, and allowed to roll, the unbalanced moment of stability acts to bring her to the upright, the moment gradually diminishing to zero at the upright, so that the angular velocity is then greatest, and the energy of the ship will carry her to a certain angle on the other side against the moment of stability, which now acts against the motion. So we see that by reducing the metacentric height, and so the moment of stability, the ship is brought to the upright more slowly, and the rolling is not so violent. Steadiness, if derived from a decrease of the metacentric height, is limited by the necessity for sufficient initial stability for safety. If, on the other hand, we increase the moment of inertia to lengthen the period, we have the roll once begun of greater range and longer sustained. But if by means of a moderate metacentric height and increase of the moment of inertia a long natural period is obtained, this may be somewhat lengthened, and, what is of greater importance, the rolling considerably limited by the use of bilge keels and water chambers. The following table contains the results of Mr. Froude's experiments with a model of the Devastation, fitted with bilge keels which, on the full sized ship, would represent the various depths given in the table:

Model fitted with—	Number of double-rolls before coming to test.	Period of double-roll.
		Seconds.
(1) No bilge-pieces	31½	1.77
(2) Single 21-inch bilge-piece on each side	12½	1.9
(3) Single 36-inch bilge-keel on each side	8	1.9
(4) Two 36-inch bilge-keel on each side	5¾	1.92
(5) Single 72-inch keel on each side	4	1.99

We can increase the period by increasing the radius of gyration or decreasing the metacentric height. We can increase the radius of gyration by moving weights farther away from the axis of oscillation. For example, by winging out weights.

Fig. 2.

Curves of Extinction of U.S.S. Tennessee



Note. If the maximum angle of any roll is the ordinate of a certain point of the curve, the maximum angle of the succeeding roll will be the ordinate at one interval beyond that point.

Raising weights also tends to increase the radius of gyration, if they are above the center of gravity, but such vertical motions of weights have an effect upon the position of the center of gravity and so alter the metacentric height. The much greater effect of the vertical motion on the period is shown by the following table:

Condition.	Period.
	Seconds.
6,000-ton ship	7.00
100 tons raised from 15 feet below to 15 feet above the center of gravity	7.70
100 tons at level of center of gravity winged out 15 feet	7.028

The Inflexible, with a metacentric height of 8 feet and a very great moment of inertia, due to her heavy side armor, has about the same period as the Duilio, with only 3 feet metacentric height and a much smaller moment of inertia.

Gun-vessels and small craft generally have short periods, due to a small radius of gyration and the necessity for securing a good metacentric height. Turning to armored vessels, the shortest periods observed are with shallow coast-defense vessels. In the following table the periods of various types of vessels and for particular vessels are given:

	Period.		Period.
	Seconds.		*Seconds.*
Gun-vessels	2 to 3	Inconstant	8
Dispatch vessels, sloops, &c	3 to $4\frac{1}{2}$	Modern swift cruisers	8
Dolphin	4	Monitors	$2\frac{7}{10}$ to 3
Unarmored corvettes and frigates with both sail and steam power	5 to 6	Inflexible	5.35
Tennessee	$6\frac{2}{5}$	Devastation	$6\frac{3}{4}$

When a ship is at sea in waves, the stiffness or the tendency of the ship to place herself normal to the effective wave-slope increases as the statical stability or approximately as the metacentric height increases. The vessel, then, which best stands up under canvas or is stiffest tends to follow the waves most closely, while, on the other hand, a crank ship is most likely to be steady, allowing the waves to pass her, and as the righting moment is less the ship has less tendency to accompany the wave. On account of the advance of the wave, the wave normal oscillates from upright at crest to upright at the hollow of the wave, at a rate depending on the velocity of advance of the wave, while the ship tends to perform her oscillations about each instantaneous position of the wave normal at a rate depending on her still-water period. Hence we see that the behavior of a ship amongst waves depends on the relation between the period of the wave and the period of the ship. If the natural period of the ship is very small, as compared with the wave period, the vessel will nearly follow the wave being upright at crest and hollow and attaining her maximum inclination where the wave is steepest. This cannot be attained in practice, as the ship must either have a great metacentric height or a small moment of inertia, the nearest approach being in the case of the monitors.

An important case is where the natural period for a double roll equals the period of the waves. In such a case the ship accumulates motion and the range increases in the same manner as a pendulum does which receives successive impulses at the extremities of its swings, and the ship would capsize if it were not for the resistance developed, the practical limit of accumulation being, according to Mr. Froude, when the angular velocity is so quickened as to develop a resistance capable of balancing the tendency to extend the range, the conclusion being that the best means to produce steady ships, which shall not accumulate large angles of roll, was to increase the natural period as much as possible. Ships with short periods are the heaviest rollers, as will be seen by comparing the behavior of the Prince Consort and Hercules in heavy weather, the former with a period of five seconds having an amplitude of roll of 46°, while the latter with a period of eight seconds only rolled through 25°.

The following table gives the periods and lengths of some of the largest waves that have been observed:

Locality.	Observer.	Length.	Period.
			Seconds.
North Atlantic	Captain Motter	2, 750	23
South Atlantic	Sir James Ross	1, 920	....
European waters	....	2, 000	19¾
Bay of Biscay	....	1, 320	16
Atlantic storm waves	Dr. Scoresby	500 to 600	10 to 11

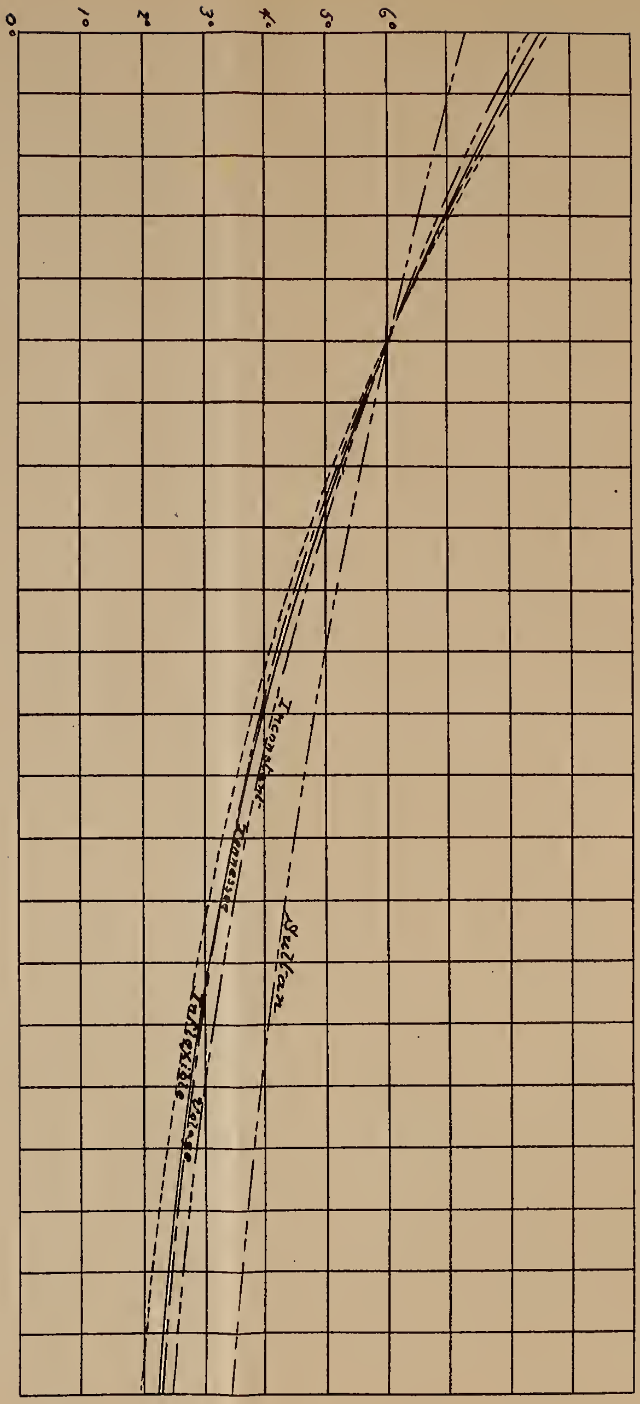
Such enormous waves are unusual, and waves of 600 to 700 feet would be regarded as very large waves, as, according to the best authorities, a wave of 3,000 feet in length and twenty-four seconds period is the extreme limit of size yet proved to exist.

What may be called large storm waves have periods varying from six to seven seconds, corresponding to lengths of from 400 to 600 feet; so that the Tennessee is not likely to encounter any waves that might cause excessive rolling due to harmony of wave impulse, as her double period of thirteen seconds corresponds to a length of 865 feet.

Table giving the mean period of waves in various parts of the world:

Where met with.	Period.
	Seconds.
Atlantic trades	5. 8
South Atlantic region, westerly winds	9. 5
Indian Ocean region, easterly winds	7. 6
Indian Ocean region, trade winds	7. 6
China Sea	6. 9
West Pacific	8. 2

Fig. 3.



Comparative Curves of Extinction,
of different ships, brought to a common inclination of 6°

The blank form for record of deep-sea waves issued by the Hydrographic Office, if properly filled in, would afford valuable information on this point, but so far none of the observations have been sufficiently consistent to be of any use.

If we examine the accompanying table, we see that the metacentric height and period of the Tennessee agree very well with those of the Inconstant and Volage, and the values of the constants in the differential equation to the curve of extinction are such as we should expect from a comparison of the curves shown in Fig. 3.

Ship.	Period.	Metacentric height.	Equation.
Greyhound	3.88		$-\Delta\theta = .0198\,\theta + .0462\,\theta^2$
Perseus	3.83		$-\Delta\theta = .0187\,\theta + .0097\,\theta^2$
Inconstant	7.99	2.8	$-\Delta\theta = .035\,\theta + .0051\,\theta^2$
Tennessee	6.4	3.11	$-\Delta\theta = .0323\,\theta + .00714\,\theta^2$
Volage	5.79	3.00	$-\Delta\theta = .028\,\theta + .0073\,\theta^2$
Narcissus	5.19		$-\Delta\theta = .037\,\theta + .008\,\theta^2$
Devastation	6.76	3.7	$-\Delta\theta = .072\,\theta + .015\,\theta^2$
Sultan	8.87		$-\Delta\theta = .0267\,\theta + .0016\,\theta^2$
Inflexible	5.35	8.00	$-\Delta\theta = .04\,\theta + .008\,\theta^2$

We conclude that the moderate metacentric height and relatively large moment of inertia give to the Tennessee a fairly long period, though the fact that she is so very easy is not altogether due to the long period, but to the fact that she altogether escapes the performance of great oscillations; for uneasiness is due to the reciprocating stress brought to bear during oscillation on parts distant from the axis of oscillation, this being intensified by increased range even with a shorter period, as well as by a short period with a given amplitude.

A water chamber consists of a tank across the ship, which when in use is filled with water to a certain most effective height, found by experiment. The shape is so arranged that as the ship rolls the water moves from side to side so as to retard the motion. The water lags behind, acting, in fact, to produce just the reverse of what the men do when getting up an initial roll by rushing from side to side keeping half a period ahead of the ship. The effect of the loose water in the boilers is shown in the lengthening of the period from 6.40 seconds to 6.533 seconds, and is graphically shown on the curves of extinction in Fig. 2. There are ten boilers' weight of water; fill one to the working level is 13.2 tons; to fill one full is 18.4 tons.

Water chambers are most effective for small angles, while bilge keels are most useful in reducing large angles of roll, as the following table will show:

[H. M. S. Edinburgh. 100 tons of water in chamber.]

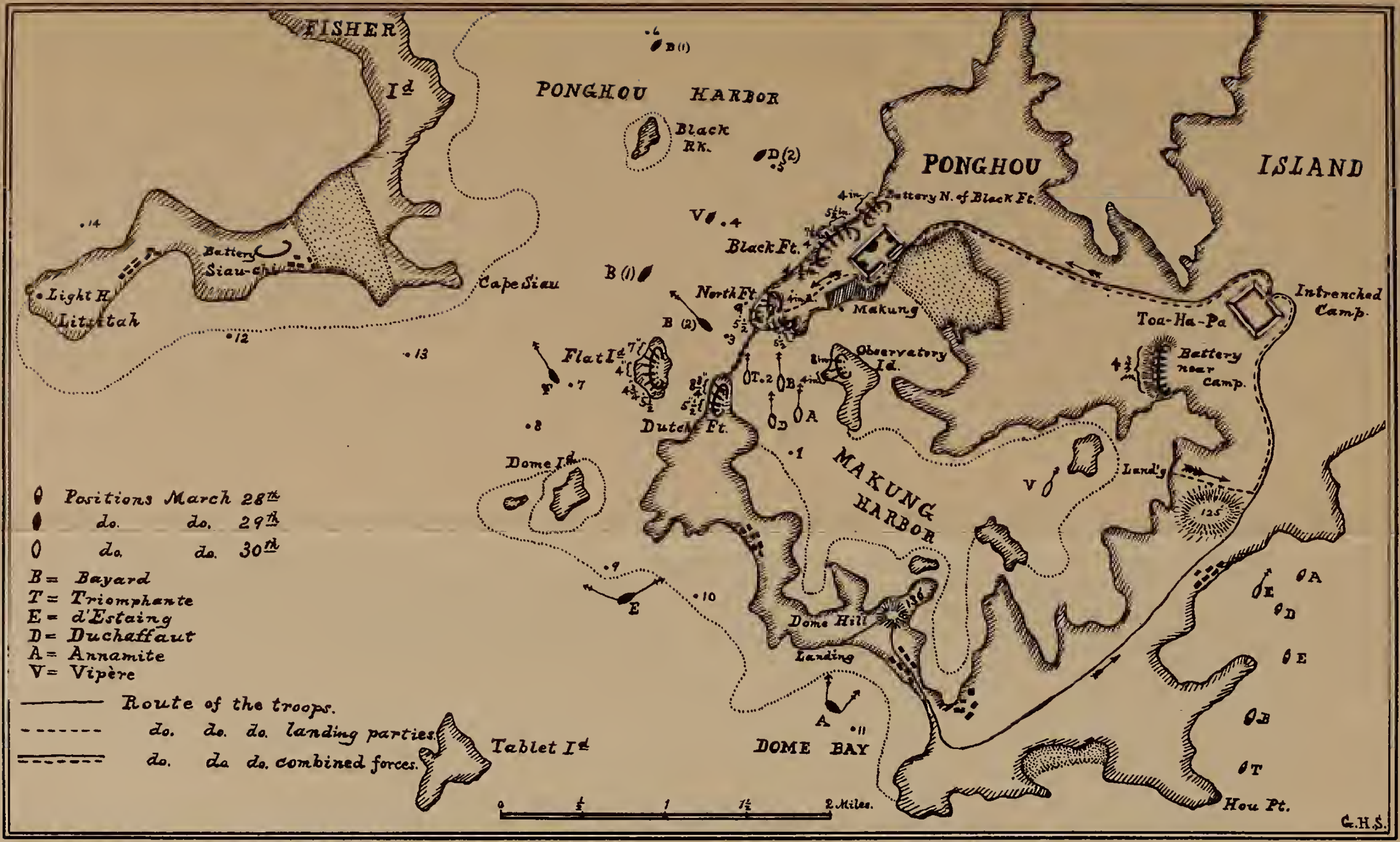
Chamber for 3° roll added 6 times as much as 2 feet additional bilge keel.
5° roll added 3 times as much as 2 feet additional bilge keel.
12° roll added 3 times as much as 2 feet additional bilge keel.
18° roll added ½ time as much as 2 feet additional bilge keel.

We see then that both forms are useful. In tolerably smooth water engagements should find the water chamber the best, but for large angles of roll the bilge keel is most effective.

General table of results.

U. S. S. TENNESSEE.

Length between perpendiculars	feet	335
Beam	do	$45\frac{1}{6}$
Draught (mean)	do	21.5
Displacement	tons	4,760
Metacenter above center of buoyancy	feet	9.5854
Center of buoyancy below water-line	do	7.964
Metacenter above water-line	do	1.6214
Still-water period, water at working level in boilers	seconds	6.533
Still-water period, boilers full	do	6.40
(Radius of gyration)^2 = .16 (b^2+h^2), (h = mean depth = 35 feet; allowing for bulwark and sheer b = beam)		522.5
Values of extinction constants in the equation—$\Delta\theta = a\theta + b\theta^2$:		
Water at working level in boilers		$a = .0548$ $b = .00144$
Boilers full		$a = .0323$ $b = .00714$


FISHER I^d
PONGHOU HARBOR
Black Rk.
PONGHOU ISLAND
Battery N. of Black Ft.
Black Ft.
North Ft.
Makung
Battery Siau-chi
Light H.
Litsitah
Cape Siau
Flat I^d
Dutch Ft.
Observatory I^d.
Toa-Ha-Pa
Intrenched Camp.
Battery near Camp.
MAKUNG HARBOR
Land'g
Dome I^d.
Dome Hill
Landing
DOME BAY
Tablet I^d
Hou Pt.
Positions March 28th
do. do. 29th
do. do. 30th
B = Bayard
T = Triomphante
E = d'Estaing
D = Duchaffaut
A = Annamite
V = Vipère
Route of the troops.
do. do. do. landing parties.
do. do. do. combined forces.
0 ½ 1 1½ 2 Miles.
G.H.S.

VIII.

[The last publication of this office, General Information, Series No. IV, described the engagement between the French and Chinese forces in 1884, in the Min River. The present number completes the narrative of important naval operations during the Franco-Chinese war.

The successful campaign of the French commander-in-chief, the late Admiral Courbet, has secured for him a distinguished place in naval history.

Since the close of our civil war, in 1865, no naval commander has conducted operations of such magnitude as those which were carried on in China under his direction and command. His constant devotion to duty, his many seamanlike qualities of the highest order, and his rare ability to command must excite the admiration of naval officers and entitle his methods to the attentive study of the military profession at large.]

THE CAPTURE OF THE PESCADORES ISLANDS.

(Translation from French and German naval publications by Lieut. W. H. Beehler, U. S. N.)

Admiral Courbet contemplated an attack on the Pescadores Islands early in the spring of 1884, when the French commenced their operations in China, and before Kelung had been captured.

The geographical position of the Pescadores Islands is admirable and even superior to that of Hong-Kong. The excellent harbor of Makung, in the island of Pong-Hou, is the best in these waters and is of the greatest strategic importance.

The harbor is perfectly protected in all seasons and easily accessible by the largest vessels. Its average depth is about 6 fathoms and its area about 2,200 acres.

In time of peace vessels may find this a harbor of refuge from the violence of the northeast monsoons, and during war it may serve as a base of operations, especially valuable on account of its proximity to the Chinese coast. The shores of the harbor are admirably adapted for the erection of permanent buildings, storehouses, machine shops, and coal depots, and in the course of time it could be made a complete naval station.

Pong-Hou Island is so small that it can be efficiently protected by a small garrison, while the native inhabitants, numbering 30,000, are peaceable and can be easily influenced to respect the established authorities.

The Chinese recognized the importance of these islands and utilized them as a rendezvous for troops destined for the defense of Formosa Island, the distance from the latter's west coast being only 5 miles on the 23½ parallel of north latitude.

In accordance with the French regulations, established in November, 1884, only those vessels could be searched which were found within 5 sea miles of the Formosa coast, so that those bound for the Pescadores Islands were not within the blockade limits, and troops and war material could be landed on the Pescadores Islands with impunity.

When once landed it became an easy matter to transport these troops and war material to Formosa Island during the night, notwithstanding the vigilance of the French blockading fleet. This was done during the entire winter of 1884–'85.

Steamers loaded with arms and men (generally from 1,000 to 1,500 men) made regular trips to these islands from various points on the Chinese coast, especially from Amoy to Makung.

These troops, as a rule, coolies of little or no military training, served to replace those which had previously formed the garrison of the islands, and their arrival permitted the transfer of the latter to the then more important positions on Formosa. As the distance to Formosa was short the transfer was readily made in favorable weather in small junks.

The French had decided to establish their base at Kelung, a little harbor on the northeast coast of Formosa Island, in the vicinity of rich coal mines. Captain Fournier, who had counseled this step against the advice of Admiral Courbet, thought that the northeastern corner of Formosa Island could readily be held by a few hundred troops, so that the fleet could obtain coal from these mines.

Kelung was bombarded in August, 1884, the forts, one of which was armored and mounted Krupp guns, were demolished, and the harbor was occupied in the beginning of October, 1884.

But up to April, 1885, no further progress had been made, and the coal mines had not been captured, while the French troops, who at one time numbered 3,000 of all arms, suffered heavy losses.

In the course of the preceding winter the cholera raged among the troops at Kelung to such an extent that out of the 1,800 men landed at the time of its capture in October, 1884, there were but 600 available for duty in February, 1885.

Cholera did not break out on board the ships, so that the disease was attributed to the filthy condition in which the Chinese left Kelung, or, as frequently reported, to the poisoning of the wells and water supply.

With the failure to get possession of the coal mines Kelung lost all of its strategic value. The harbor is very small and dangerous. A number of accidents had happened to the French fleet, and the flagship Bayard narrowly escaped being wrecked in the harbor in sight of the enemy, which facts, together with the advent of the typhoon season, were conclusive that Kelung could not serve as the naval base of operations.

After a short cruise to the northward, in which Admiral Courbet destroyed two Chinese cruisers, he returned to Kelung on March 23, 1885, and made the necessary preparations for the capture of the Pescadores Islands.

The following vessels were selected to participate:

(1) *Bayard.*—Cruising armorclad of 5,881 tons; armament, four 9½-inch, two 7½-inch, and six 5½-inch, all B. L. R.; with twelve revolving cannon, two in each top.

(2) *Triomphante.*—Cruising armorclad of 4,127 tons; armament, six 9½-inch, one 7½-inch, six 5½-inch, and one 4¾-inch, all B. L. R.; with revolving cannon.

(3) *d'Estaing.*—Unarmored second-class cruiser, 2,256 tons; armament, fifteen 5½-inch B. L. R., and revolving cannon.

(4) *Duchaffaut.*—Unarmored third-class cruiser, 1,289 tons; armament, six 5½-inch B. L. R., and two revolving cannon in each top.

(5) *Vipère.*—Unarmored gunboat, first class, 463 tons; armament, two 5½-inch and two 4-inch B. L. R., and revolving cannon.

(6) *Annamite.*—Troop ship, 5,428 tons; armament, three 4-inch B. L. R. and two 5½-inch M. L. R.; six revolving cannon. She also carried four companies of marine infantry and fifty marine artillerymen, with two 3½-inch field guns.

At 2 p. m. on March 26, 1885, the Bayard and Annamite proceeded to Tai-Wan, the capital of Formosa, a little south of the Pescadores Islands, to join the rest of the squadron there. The next forenoon they passed the entrance to Makung harbor at a distance of 2 miles. Both ships were cleared for action prepared to return the fire from the newly built forts in the neighborhood of the light-house on Fisher Island. No shots were fired, and at 4 p. m. the ships came to anchor in the roads of Tai-Wan, where the rest of the fleet had anchored, except the Vipère, which had been obliged to seek shelter off the Chinese coast on account of the stormy weather.

A council of war was assembled that evening, during which the admiral informed the commanding officer that, according to reports of spies, the defenses of the harbor consisted of a fort on the north side of the entrance, one on the south side, called Dutch Fort, a battery on Flat Island, one on Observatory Island, and a newly built fort on Fisher Island.

There was some doubt concerning the latter, as several asserted that it was not armed, though the Chinese had been careful to circulate reports about it in the papers.

Besides these defenses a chain blocked the entrance to the harbor proper, while junks loaded with stone were ready to be sunk in the channel between Flat Island and the Black Cliffs.

The entire armament was reported to consist of six or eight Krupp guns of 8 tons and about forty old and new muzzle-loaders.

After the bombardment these reports were found to have been very inaccurate. The defenses were under the command of an American, named

Nelson, with the rank of a mandarin, and a Chinese mandarin, and consisted of the following:

(1) *The North Fort.*

	No. guns.
In the fort, 7 feet above water-line:	
4-inch Armstrong, in embrasures	3
5½-inch muzzle-loader, Vorez at Nantes, 1869, barbette	1
In front and below the fort proper, at the water-line:	
9-inch Armstrong	1
5½-inch Vorez, 1869	1
Alongside of the fort proper, about 32 feet above the water:	
6½-inch Vorez, 1869	1
5½-inch Vorez, 1869	2
Total	9

(2) *The Dutch Fort.*

In barbette:	
8¾-inch smooth-bore guns	2
5½-inch smooth-bore guns	2
Total	4

(3) *Flat Island Battery.*

In barbette, about 80 feet above the water:	
7-inch very old Chinese smooth-bore guns	2
4-inch very old Chinese smooth-bore guns	2
4¾-inch very old Chinese smooth-bore gun	1
5½-inch European smooth-bore gun	1
Total	6

(4) *Observatory Island Battery.*

32 feet above the water:	
4-inch Armstrong	2
8-inch Chinese	1
Total	3

(5) *Black Fort.*

In barbette, about 65 feet above the water:	
5½-inch smooth-bore, English	2
7½-inch Chinese smooth-bore	1
4-inch Armstrong	1
4¾-inch Chinese carronade	1
Total	5

(6) *Battery north of the Black Fort.*

4-inch smooth-bore guns	3

(7) *Battery in the harbor, near camp Toa-Ha-Pa.*

4¾-inch smooth-bore guns	6
Total for defense of the islands	36

The two last named batteries did not fire a single shot.

The fort on Fisher Island is a modern European structure, built after the outbreak of the war. It is large, roomy, bomb-proof, and intended for a battery of heavy guns. It is located on an elevated plateau with vertical sides, about 130 feet above the water, and has an admirable position to defend the entrance against an enemy approaching between Fisher and Flat Islands. Had this fort been armed as intended, the capture of the islands, at least from this side, would have been almost impossible. The fire of the ships had no effect upon it, as the Vipère and d'Estaing both fired upon it for considerable time without effecting any damage.

The Chinese have herein followed the modern European principles in having the coast fortifications built with a view of throwing projectiles upon the deck of the hostile ship in preference to engaging the sides, as formerly practiced.

In order to bar the entrance to the harbor of Makung a barrier was stretched between the North and Dutch Forts. It was made in two parts, and united by a large buoy at about one-third the distance from Dutch Fort. One part consisted of a heavy 7-inch chain, and the other of a heavy cable made of bamboo. This barrier was stretched taut by means of capstans at the shore ends, while small buoys were placed at intervals to keep it at a depth of 10 feet below the surface of the water.

In the accompanying map there are found numbers indicating positions which the French admiral assigned to the different ships for the bombardment. The following shows the values of these positions:

Positions 2 and 3 engage the batteries of Makung in the rear.

Positions 4 and 6 engage North Fort as the limit of its circle of fire and Dutch Fort in the rear.

Position 5 engages North and Dutch Forts in the rear.

Positions 5 and 6 engage the Chinese intrenched camp.

Position 7 and 8 engage the batteries on Flat Island, Dutch Fort, as the limit of its circle of fire while being sheltered from the fire of North Fort.

Position 9 engages Flat Island in the rear or Battery Sian-chi.

Position 10 engages the northern flank of Dome Hill and commands the isthmus between it and Dutch Fort, so as to prevent reinforcement of the latter or the flight of the troops.

Positions 12 and 13 engage Battery Sian-chi near the limit of its supposed circle of fire.

Position 14 engages Battery Sian-chi in the rear.

The admiral's instructions also specified:

All junks seeking safety in flight, and all Chinese troops in retreat or endeavoring to reinforce the garrisons shall be fired upon from al points. Efforts should be made to bombard the different camps, and, finally, to avoid placing oneself in the direct line of fire of a more heavily armed ship or of a ship which can fight to better advantage.

As it was not known whether the battery at Sian-chi was armed or not, the admiral issued three different programmes for the attack. From these it will be seen that it was not intended to have the troop-ship Annamite take part in the action or to be exposed to the enemy's fire, but merely to support the landing of her troops by her fire.

The three programmes were:

Programme 1 (*supposing Sian-chi Battery to be armed*).

	Positions.
Bayard Triomphante } according to the circle of fire of the fort	13 and 12
Duchaffaut (engage Sian-chi in the rear)	14
d'Estaing	9
Vipère	9
Annamite	11

Programme 2 *and* 3 (*Sian-chi not armed*).

PROGRAMME 2.	Positions.	PROGRAMME 3.	Positions.
Bayard	4	Bayard	3, 2, or 1
Triomphante	7	Triomphante	7
d'Estaing	8	d'Estaing	8
Duchaffaut	9	Duchaffaut	9
Vipère	6 or 5	Vipère	6 or 5
Annamite	10 or 11	Annamite	10 or 11

At 3 p. m., March 28, the French squadron got under way and steamed out from the roads at Tai-Wan, northwestward, in column of vessels, in the following order: Bayard, flagship of Vice-Admiral Courbet, Triomphante, d'Estaing, Duchaffaut and Annamite.

The squadron came to anchor at 6 p. m. about 2 miles east of the entrance to Pong-Hou Harbor.

According to the official notice to mariners the light on Fisher Island at Litsitah was extinguished during the war. As the night came on, it was noticed that this light was burning, so that it was evident that something unusual was being done on the island. The Duchaffaut was thereupon sent to cruise off the entrance to the harbor, where she remained during the night, until joined by the rest of the squadron at daylight. Nothing was discovered, notwithstanding the most vigilant lookout. It is very probable that several merchant steamers took advantage of the opportunity to escape. At all events no vessels were found in the harbor at the time of the bombardment, although it is well known that steamers had been arriving regularly with provisions, &c., for the troops on these islands and Formosa.

At 5.30 a. m., Sunday, March 29, the signal was made from the flagship to get under way and to proceed in the order adopted the previous day. At 6 a. m. the signal to "clear ship for action" was made from the flag-ship, and the squadron proceeded in column of vessels to the westward at about 600 yards from the shore.

Occasional shots were fired from the revolving cannon in the tops at dense groups of curious observers, who had gathered on the heights and at prominent points, but the fire of the heavy guns was reserved for more important work.

At 6.45 a. m. the d'Estaing anchored at position 9, while the Annamite took up position 11, where she endeavored to bring her broadside to bear against the shore by means of kedge and warp, so as to be ready to send her landing force ashore at any moment desired.

The weather was calm, and a cloudless sky promised the crews a hot day under the direct burning rays of a tropical sun. The other ships proceeded on their way westward, from thence reinforced by the Duchaffaut, which joined the admiral off Dome Island, and reported the fact that the Sian-chi Battery was not armed. The admiral then signaled "programme 2" and the course was shaped for Pong-Hou Harbor.

The Bayard then anchored in position B (1), the Triomphante at T, while the Duchaffaut went on to D (1) to engage the North Fort. In the mean time the fight between the battery on Flat Island and the d'Estaing had commenced. The former opened fire on the d'Estaing at 7 a. m. without any effect. The latter promptly answered with her fifteen 5½-inch guns, and supported by the fire of the Triomphante, silenced this battery in the course of a quarter of an hour. The garrison was seen to be in full flight in wild disorder; some threw themselves into the sea to swim across to Dutch Fort. The revolving cannon were then brought into action. These made short work with the fugitives, so that in a few minutes all resistance ceased.

In the course of a half of an hour the two armored ships destroyed the Dutch Fort, so that the squadron was enabled to devote its entire attention to the North Fort, which constituted the chief defense and still continued its fire.

At 8 a. m. a shot was heard from the direction of Litsitah, and the Vipère came in sight, having been driven under the lee of the Chinese coast by the storm of the 26th and 27th instants. The flag-ship signaled for her to take the position 5.

The fire against the North Fort continued, when a shot from the Black Fort striking close under the bows of the Duchaffaut announced its participation in the combat. The Duchaffaut then went into the position D 2, and soon silenced this fort.

Up to this time the French had suffered no loss. The enemy's shot either passed over or fell short, and it seemed as if the Chinese idea of efficient firing consisted in the rapid discharge of the guns without wasting time in aiming them at the enemy.

The Annamite opened fire upon the two villages in front as soon as she had sprung her broadside to bear. Her new high-powered 4-inch guns were very effective and soon cleared the coast of men, so that the landing of the French troops could have been effected without opposition at any time after 8 a. m.

The effect of the bombardment of the Dutch and North Forts was disastrous, and the well-aimed projectiles gave evidence of the excellent instruction and training of the crews of the French squadron.

The North Fort, with its nine guns, soon became a shapeless mass of débris. At intervals the flames reached the numerous powder magazines, four or five of which exploded with great violence.

The French next turned to the battery on Observatory Island. This battery had fired upon the Bayard during the engagement, but without effect. The projectiles fell short or passed over, as did those of the North Fort.

It is wonderful that the Chinese gunners should have failed to hit the French ships at such short range. The guns were, however, frequently loaded with powder only, and sometimes elongated projectiles were fired from smooth-bore guns, which naturally tumbled and went in every conceivable direction.

The bad shooting can also be accounted for by the fact that the gunpowder was manufactured in huts, according to the methods used for centuries by the Chinese, so that it was entirely unreliable in its results. None of the guns, exceepting those in the North Fort commanded by the American mandarin, had any sights.

The bombardment of the harbor continued with intervals during the entire day. Lucky shots from the Duchaffaut caused the explosion of two powder magazines.

During breakfast, about 11 a. m., the Bayard took up the position B_2 and the Duchaffaut that of D_2; the other vessels remained in the positions previously mentioned.

The fire from the Chinese forts ceased after some thirty shots had been fired from them. The bombardment was strictly finished when the village of Makung was burned. The American mandarin, Nelson, was then observed to mount a horse, being the last to leave the North Fort. He had been faithful to his command, and if his Chinese colleagues had followed his example, he would have doubtless been saved, but he was sacrificed to the fury of the mob outside of Makung.

At 1 p. m. the Duchaffaut got under way, with the admiral on board, and proceeded to the position of the Annamite in order to assist in the landing of the troops. At 4.30 p. m., 450 infantry and artillery were landed on the beach below Dome Hill by means of the boats of the Duchaffaut and Annamite. The Dome heights, 130 feet above the sea-level, were gained and two of the field guns were placed in position. The troops were encamped here for the night and at daylight took up their march to the North Fort by way of the Makung village.

During the night the squadron investigated the nature of the barrier across the channel between the Dutch and North Forts. The buoys were supposed to mark torpedoes, but at daylight the barrier was removed without difficulty.

The Chinese regulars then occupied Observatory Island in force, and suddenly opened fire on the boats of the Bayard and Triomphante. One sailor of the Triomphante fell under this fire. The Bayard's revolving cannon returned the fire, and soon put the enemy to flight; shortly after which the Duchaffaut's landing party occupied the island.

Early the same morning, March 30, the Triomphante sent her landing party to Flat Island. It collected Remington rifles with a lot of ammunition, and destroyed the great guns with gun-cotton.

At 9 a. m. the Annamite received orders to enter the harbor of Makung, and at 10 a. m. she anchored at A. The other vessels came to anchor inside of the harbor at 11 a. m., except the d'Estaing, which went to the eastward of Pong-Hou Island. The Vipère anchored near the place selected for the landing of the seamen, as indicated on map. The d'Estaing took position outside the strip of the land upon which this landing was to be made, and over which the force landed from the Annamite was to pass. The fire of these two vessels effectually covered the movements of the French force on shore.

THE MARCH OF THE TROOPS.

The troops commenced their march at 7 a. m. on March 30, and at 2 p. m. reached the selected plateau, which is about 125 feet above the sea-level, and 65 feet higher than any of the surrounding country. The Chinese regulars had a small intrenched camp on the eastern side, and an engagement followed in which the French captured the camp after a loss of one killed and two wounded. The Chinese left 100 dead in the camp. The movements of the troops, and the effect of volleys, the only order of firing practiced in fighting with the Chinese, could easily be seen by means of spy-glasses on board the ships. The Chinese survivors fled in wild disorder. This confusion was enhanced by the vigorous fire of the d'Estaing and Vipère, which shelled the Chinese from off the eastern side of the island and from within the harbor.

The Chinese then reassembled at Toa-Ha-Pa, and numbered about two thousand. The French troops bivouacked in the captured camp for the night without further resistance.

At daylight of March 31 the troops resumed their march, reinforced by the landing parties from the Bayard and Triomphante, which had been sent from these ships and landed on the harbor side of the heights occupied by the marines.

At noon the combined French forces reached the vicinity of the Chinese camp at Toa-Ha-Pa. This was a small fort with an entrance on the northeast side. An attempt was made to drive out the Chinese by the 2½-inch field guns of the Bayard and Triomphante without success. It was then decided to storm the works and drive the enemy out at the point of the bayonet.

This dangerous movement was successfully carried out with the loss of but two killed.

The French gained possession of the camp at 2 p. m. and found about two hundred killed and wounded Chinese in the works. The rest of the Chinese fled to the northward, and most of them managed to escape to Formosa and China by means of junks. The Chinese mandarin escaped in this manner, after having been wounded by his own troops.

He subsequently arrived at Amoy, when, in accordance with the ancient custom, he was promptly beheaded.

At 5 p. m. the French forces reached the limits of the village of Makung. The abandoned camp was soon turned into comfortable barracks for the marines, while the sailors proceeded to the North Fort, which had been almost completely demolished by the bombardment. The place was found to be completely deserted.

Two ships with one company of marines were sent to take possession of Fisher Island on April 2, and to occupy Fort Sian-chi and the Litsitah light-house. There was no resistance.

A subsequent reconnaissance over the island revealed no further opposition. Large quantities of arms, powder, saltpeter, and shot were found and a number of heavy guns, which were destroyed by means of gun-cotton.

NOTES

ON

SHIPS, GUNS, TORPEDOES, ETC.

SHIPS.

ENGLAND.

VESSELS LAID DOWN DURING THE PAST YEAR.

TRAFALGAR AND NILE.

These ships are being built at Government dock-yards, the former at Portsmouth and the latter at Pembroke. They were laid down January 18, 1886, and January 25, 1886, respectively, and are the largest ships yet designed for the British service. They will be somewhat of the type of the Dreadnought, having two revolving turrets on the fore-and-aft line amidships. In general appearance, though, they will more nearly resemble the Admiral class of barbette ships, as they carry a broadside battery in a superstructure the full width of the ship between the turrets. The armor, which is compound, will be 18 inches thick on the turrets, and 20 inches, maximum, on the belt extending about two-thirds the length. This belt rises in the waist to a height sufficient to protect the vital parts of the ship, and on the citadel thus formed a maximum thickness of 20 inches of armor is also carried. The principal dimensions are: Length, 365 feet; beam, 73 feet; displacement, 12,000 tons.

It is expected that they will be launched in 1888, and completed for sea by 1890, at an estimated cost of about $5,000,000 each. (For further information see p. 73.)

IMMORTALITÉ AND AURORA.

These steel-belted cruisers are similar in all respects to the five "Orlando" class building by contract (described on p. 79).

The Immortalité was laid down at Chatham dock-yard December, 1885, and the Aurora at Devonport.

SWALLOW AND BUZZARD.

These two composite vessels, though classed as gun vessels, are essentially cruisers, and, for their size, carry very formidable batteries. They are both being built at Sheerness dock-yard, and will be completed during the present year.

The Swallow was laid down January, 1885, launched October 27, 1885, and is expected to be completed for sea by April, 1886. Her displacement is 1,040 tons; length, 195 feet; beam, 28 feet; draught of water, 12 feet; estimated speed, 14 knots. The motive power will consist of two sets of independent compound engines, of 1,500 I. H. P., driving twin screws. The armament will be eight 5-inch B. L., of which four are on sponsons, and eight Nordenfeldt and Gardner machine guns. The engines and boilers are protected by a ½-inch steel inclined deck, and also by the arrangement of coal in bunkers. The rig is barkentine, spreading sufficient canvas to work under sail; while a coal supply of 280 tons is to be carried. The complement of officers and men will be 100. The estimated cost of the Swallow complete for sea is about $322,000.

It is the intention of the Admiralty to increase this class of cruisers.

RATTLER—WASP—LIZARD—BRAMBLE.

A new class of composite gun vessels being built by contract; the two first at Elswick, by Armstrong & Co., and the last two at Belfast, by Harland & Wolff. They were commenced October, 1885, and will be completed within the year.

Their displacement is 670 tons; estimated speed, 13¾ knots; I. H. P., 1,000. The battery intended is six 4-inch B. L. and a supply of machine guns. They will spread a sufficiency of canvas to work under sail, and will carry a coal supply of 200 tons.

ARCHER—BRISK—COSSACK—MOHAWK—PORPOISE—TARTAR—SERPENT—RACOON.

These are the improved "Scout" type of torpedo-cruisers commenced during 1885; the first seven by Thompson, on the Clyde, the last two at Devonport by the Government. They are all built of steel; have a barkentine rig, and an estimated speed of 17–18 knots, with 4,250 I. H. P. The Serpent and Racoon have had their I. H. P. increased to 4,500 under forced draft, with a probable increase of speed to 18 knots.

The Archer was launched December, 1885; the Mohawk in February, and the Brisk in April, 1886. The others will all be launched, and some will be completed for sea, during the current year. (For further information see p. 85, 86, 139.)

GRASSHOPPER—SANDFLY—SPIDER, AND N**.

A new type of small vessel, known as "torpedo-boat catchers" or "torpedo-boat chasers." They were commenced November, 1885, the Grasshopper at Sheerness, the Sandfly and Spider at Devonport, and the unnamed one by Laird at Birkenhead. They are built of steel, and are intended to do the work of torpedo-boats on the open sea, and also to engage and destroy the torpedo-boats of an opposing force.

The displacement is 450 tons; length, 200 feet; beam, 23 feet; mean draught, 8 feet. The estimated cost of hull and engines is about $69,000; ordnance and torpedo outfit, $52,000. It is expected they will be completed within the year. (For further information see p. 87, 140.)

VESSELS LAUNCHED.

CAMPERDOWN.

This barbette battle-ship of the Admiral class was launched November, 1885, at Portsmouth dock-yard. She was commenced in 1882, and will be completed for sea by 1887. She is a sister ship to the Benbow in all respects, except the main battery, which will consist of four 13.5-inch 63 ton B. L., two in each barbette; and six 6-inch B. L. in broadside. The estimated cost of this ship, with her battery and fitting complete for sea, will be about $4,200,000.

ANSON.

A sister ship in every respect to the Camperdown; was launched February 17, 1886, at the Pembroke dock-yard, where she was commenced in 1883. She will be completed for sea in 1887, at an estimated cost of about $4,100,000.

(For further information of this class see page 41.)

HERO.

A single-turret battle-ship of medium size; was launched at Chatham dock-yard October 27, 1885, where her keel was laid April 21, 1884. She is a sister ship to the Conqueror, laid down at the same place, 1879, and completed in 1883.

One steel signal mast abaft the smoke-pipe is fitted with a military top. The estimated total cost of the Conqueror, with battery and fitings complete for sea, is about $2,400,000, and of the Hero about $2,300,000. (For further information relating to Hero see page 71.)

MERSEY, SEVERN, THAMES, AND FORTH.

Unarmored steel, protected cruisers, with complete steel deck, 2 inches thick on the horizontal and 3 inches on the inclined sides. The horizontal portion is 1 foot above the water-line, and the lower edge of the sides is 4 feet below it. This deck slopes down forward to the point of the ram, and aft, to cover the and rudder-head steering gear, A 9-inch steel conning tower on the after end of forecastle affords protection to the commanding officer and helmsmen. Two steel masts, fitted with a light fore and aft rig, each carry a military top in which machine guns are mounted. These vessels are all building at Government dock-yards; the Mersey at Chatham was laid down in 1883, and launched March 31, 1885; the Severn at the same place was laid down in 1884, and launched September 29, 1885; the Thames, at Pembroke, April, 1884, launched December 3, 1885; and the Forth at Pembroke in 1884, not yet launched. They are designed for a speed of 17 knots, and 6,000 I. H. P. with forced draft. The Mersey, the only one tried, has developed a speed of 17.5 knots, on light draught, and 6,626 I. H. P. The motive power consists of three cylinder, horizontal, compound engines driving twin screws. The coal supply is 750 tons; the complement, 300 officers and men; and the battery, two 8-inch 13-ton, B. L., central pivot guns, one forward with an arc of fire 260 degrees, and one aft with an arc of 240 degrees. On the main deck ten 6-inch 89-cwt. guns are mounted in broadside, each having a train of 120 degrees. On the main deck, on a line with the 6-inch batteries, on each side, are four projecting half towers for Nordenfeldt or rapid-fire guns; two similar half towers on the upper deck in the waist, and one Gardner machine gun in each top. Whitehead torpedoes will be carried, which may be discharged through six above-water tubes, three on each broadside, on the lower deck. In addition to the protective deck, extensive coal protection is furnished by bunkers in wake of the machinery space, both below and over the protective deck. The dimensions are: length, 300 feet; beam, 46 feet; draught, 20 feet; displacement, 3,550 tons. The estimated cost of these vessels, with batteries and fittings complete for sea, is about $1,100,000 each.

ICARUS.

This ship is one of six large composite gun vessels built at Government dock-yards, the first of which, the Reindeer, was launched at Devonport in 1883. The last one, the Melita, laid down at Malta in 1883, is not yet launched.

The Icarus was laid down at Devonport August 18, 1884, and was launched July 26, 1885. She is the only one of the class fitted for forced draft, and was designed for a speed of 12.5 knots and 1,200 I. H. P. The steam trial with natural draft took place December 18, 1885, outside of Plymouth, when a three-hour, full-speed trial was made with the following mean results: steam in boilers, 84 pounds; vacuum, 25.2 inches; revolutions, 89.8; pressure upon pistons, high, 34.8 pounds—low, 11.8 pounds; I. H. P., 898; speed, 11.5 knots; coal consumption, 2.09 pounds per I. H. P. On February 6, 1886, a four-hour speed trial with forced draft was made, with mean results as follows: Steam in boilers, 93 pounds; vacuum, 24 inches; revolutions, 102; pressure upon pistons, high, 40.4 pounds—low, 14.9 pounds; I. H. P., 1,236; speed, 12.9 knots. The maximum results obtained during this trial were: revolutions, 106; I. H. P., 1,323; speed, 13 knots. The first trial was with the ship drawing 10 feet forward and 13 feet 11 inches aft; at the second trial her draught was 10 feet 2 inches forward and 14 feet 3 inches aft. The load draught is 11 feet 10 inches forward, 14 feet 4 inches aft.

The six ships of this class are similar in all respects, being of 970 tons displacement, 167 feet long, 32 feet beam, bark-rigged, and carrying batteries of eight 5-inch B. L., four of which are on sponsons and four in broadside; Nordenfeldt and Gardner machine guns are also carried. The engines are two-cylinder horizontal compound, driving one two-bladed feathering-screw. The boilers are three in number; cylindrical, 16 feet 9 inches long, 7 feet 2 inches in diameter. A coal supply of 150 tons is carried, and a complement of 100 officers and men. The estimated cost of each complete for sea, with battery and fittings, is about $320,000.

CURLEW—LANDRAIL,

Steel gun and torpedo vessels; were both laid down at Devonport dock-yard in January, 1885. The Curlew was launched October 23, 1885, and the Landrail January 19, 1886. They are intended as cruising gun-vessels in time of peace, but are fitted with torpedo-discharging tubes, one in the stern, one on each bow, and one on each quarter, to enable them to be used as torpedo cruisers when desired. They carry a battery of one 6-inch B. L. and three 5-inch B. L. pivots, also rapid-firing guns, Nordenfeldt and Gardner machine guns. In addition provision is made for carrying Whitehead torpedoes. Their displacement is 785 tons; length, 195 feet; beam, 28 feet; draught, 11 feet. Two hundred and fifty tons of coal will be carried, and a crew of 90 officers and men. The engines consist of two sets of two-cylinder horizontal compound type, driving twin screws. They were designed for a speed of 14 knots, and 1,200 I. H. P. with forced draft, but this has been exceeded by the Curlew. Her natural-draft trial took place February 1, 1886, with the following mean results of four hours: steam in boilers, 96 pounds; vacuum, 24.7 inches; pressure on cylinders, high, 43.5 pounds—low, 11.9 pounds; revolutions, 167.6; I. H. P., 890; speed, 12.9 knots; coal consumption, 2.8 pounds per I. H. P. On February 3, 1886, the four hours' forced-draft trial was made with mean results as follows: Steam in boilers, 105 pounds; vacuum, 24 inches; pressure on cylinders, high, 56.4 pounds—low, 15.7 pounds; I. H. P., 1,262; speed, 14.5 knots. The maximum results in this trial were: revolutions, 190.5; I. H. P., 1,400; speed, 15 knots; the ship being at her load displacement on both trials. The estimated cost of these vessels complete for sea, with battery and torpedoes with their fittings, is about $310,000 each.

STEAM TRIALS.

IMPÉRIEUSE—WARSPITE.

These vessels form a unique type of armored cruisers, and were built at Government dock-yards; the former being laid down at Portsmouth, August 10, 1881, and floated out of the dock in which she was built December 18, 1883. The latter was commenced at Chatham in 1881, and was launched in 1884.

They are brig rigged, have powerful ram bows, and a protecting belt of compound armor 139 feet long, 8 feet wide, 10 inches thick. A steel protective deck 2 inches thick over the belt, and 3 inches thick under water forward and abaft the belt, from the lower edge of which it dips down to the point of the ram, and to the rudder-head, furnishes additional protection and stability to the ships. The principal dimensions are: length, 315 feet; beam, 62 feet; draught, 25 feet 6 inches; displacement, 7,390 tons. The engines were designed for a speed of 16 knots and 8,000 I. H. P. They are of the 3-cylinder, compound horizontal type, and drive twin four-bladed screws. The estimated results have been considerably exceeded in the steam trials which have taken place within the past year. 1,200 tons of coal will be carried, sufficient to enable the ships to steam for thirty-seven days at 10 knots. The complement of officers and men allowed is 400. The batteries are identical and will be composed of four 9.2-inch, 24 or 22 ton B. L. mounted in circular barbette towers, armored with 8-inch, compound plates, one forward, one aft, and one each side in the waist. The 24-ton gun is 25 feet 10 inches long, its projectile weighs 380 pounds, powder charge 175 pounds, and on trial it developed an initial velocity of 2,030 feet. On the gun-deck, six 6-inch 89 cwt. B. L. guns are mounted; the extreme guns having fore and aft fire. A powerful secondary battery of twelve 6-pounder rapid-firing guns, ten Nordenfeldt 1-inch, and four Gardner guns is provided. Whitehead torpedoes will be carried, which may charged from four above-water and two submerged tubes.

The Impérieuse had her official steam trial with forced draft outside of Portsmouth, October 14, 1885, when the following results were obtained as the mean of the four hours' run: Steam in boilers, 86.5 pounds; vacuum, starboard, 27.25 inches, port, 28 inches; revolutions, 86.85, 87.67; pressure on cylinders, 44.84 pounds, 44.6 pounds, high; 13.86 pounds, 14.04 pounds, low; total I. H. P., 9,978; coal consumption, 2.5 pounds per I. H. P. The speed was taken from the mean of four runs on the measured mile, and was 17.21 knots. The maximum results obtained during the trial were I. H. P., 10,344.7; speed, 18.2 knots. The ship was brought down to her load-draught by 700 tons of water in the double bottom, and the trial was satisfactory in all respects.

The Warspite had her preliminary trials February 23, 1886, at Maplin, with results as follows, the draught of the ship being 21 feet forward, 24 feet aft: Steam in boilers, 87 pounds; vacuum, 23.87 inches; revolutions, 85.25; I. H. P., 8,835; maximum speed, 17.4 knots.

The estimated cost of these ships complete for sea, with batteries and fittings, is, for each, about $3,100,000. (For further information of this class see p. 74.)

RODNEY—HOWE.

These barbette battle-ships of the "Admiral" type were laid down at Government dock-yards in 1882—the former at Portsmouth, and the latter at Pembroke. They are sister ships, but differ slightly in their dimensions from the other ships of the class, being of 9,600 tons displacement, 325 feet long, 68 feet beam, and 27 feet 3 inches draught. They carry batteries similar to the Camperdown and Anson; also similar engines, designed to develop 9,500 I. H. P. with forced draft, and a speed of 16 knots. They were launched October 8, 1884, and April 28, 1885, respectively.

The Rodney on her official trials, which took place in July, 1885, gave the following very satisfactory results with natural draft: Steam in boilers, 89 pounds; revolutions, starboard engines, 94, port, 93; total I. H. P., 8,262. With forced draft the steam pressure was 90 pounds; vacuum, 27.5 and 28 inches; revolutions, 104 and 103; pressures in cylinders: starboard, 59.75 and 12.83 pounds, port, 60.1 and 12.78 pounds; I. H. P., 5,598.5 and 5,558.2; total I. H. P., 11,156.76; mean speed, 17 knots. The boiler power was found to be ample, and the engines worked smoothly throughout.

The Howe had a four hours' steam trial, with natural draft, outside of Portsmouth, January 5, 1886, with the following mean results, the ship being at her load displacement: Steam in boilers, 88.25 pounds; vacuum, starboard, 29.8, port, 28.8; revolutions, 94.3 and 94.2; pressure in cylinders, 43.5 and 9.86, and 44.4 and 10.2 pounds; I. H. P., 3,810.6 and 3,922.8; total I. H. P., 7,733.4; speed, 15.872 knots; coal consumption, 1.99 per I. H. P. per hour, which, with her supply of 1,200 tons of coal, would enable her to steam eight days at a speed of about 15 knots.

On January 12, 1886, the forced-draft trials were made, the following being the mean results of the four hours: Steam in boilers, 89 pounds; vacuum, 29.7 and 28 inches; revolutions, 106.9 and 106.3; mean pressures in cylinders, 59.1 and 14 pounds, and 59 and 13 pounds, starboard and port engines, respectively; I. H. P., 5,950.82 and 5,761; total I. H. P., 11,711.8, which was 2,212 H. P. beyond the contract, and nearly 16 H. P. per foot of grate surface, the highest result yet obtained from any ships in the British service. The coal consumption was 2.17 pounds per I. H. P. per hour, and the mean speed 16.936 knots. At both trials the ship was brought down to her load-draught of 26 feet 1 inch forward and 27 feet 3 inches aft by admitting water into the double bottom. The maximum I. H. P. developed was 12,086 at a preliminary trial.

Both of these ships are being rapidly completed, and will probably be ready for sea within the year. Their estimated cost, with batteries and fittings, complete for sea, will be about $4,000,000 each.

LEANDER—ARETHUSA—PHAETON—AMPHION.

Steel-protected cruisers, built by Napier, except the last, which was built at Pembroke dock-yard. The latter was commenced in 1881, the others in 1880, and they have all been completed for sea during the past year. A steel deck 1½ inches thick protects the machinery and magazine space. They are bark-rigged, have straight stems, displace 3,750 tons, are 300 feet long, 46 feet beam, and draw 20 feet 6 inches of water. The coal supply is 1,000 tons, and the complement 257 officers and men. Two sets of two-cylinder horizontal compound engines drive twin Griffiths four-bladed screws, the I. H. P., estimated, being 5,000, and the speed 16 knots. The batteries are ten

6-inch 89 cwt. B L., six Nordenfeldt and two Gardner machine guns. Whitehead torpedoes are carried, to be discharged through two ports on each broadside, above water, on the lower deck. Two second-class torpedo-boats are also carried.

The first trials of the Leander took place in August, 1883, and were altogether unsatisfactory. The mean results were, with natural draft: steam in boilers, 81 pounds; vacuum, 26.2 inches; revolutions starboard, 94.36; port, 96.76; I. H. P., 4,233.8; maximum speed, the ship being very light, 16.2 knots. The forced-draft trials developed 4,658.3 I. H. P., and a maximum speed of 17.4 knots, the ship being at the same draught. In June, 1885, a two hours' full-speed trial was made, the ship being complete for sea, with her stores, &c., on board; 4,800 I. H. P. was developed, and a speed of 15 knots. The engine-rooms have proved to be very hot and cramped.

The Arethusa also had unsatisfactory trials, 4,666 I. H. P. being developed with forced draft; steam-pressure, 90 pounds; revolutions, 95; speed at light draught, 16.77 knots.

The Phaeton was more satisfactory, 5,575 I. H. P. being developed, with 100.3 revolutions, and 18.68 knots, on light-draught trial.

The Amphion on a six hours' trial, December 10, 1884, developed a mean I. H. P. of 5,661; steam, 8,816; pressure in cylinders, 44.6, 13.5, and 46, 13.6; revolutions, 95; speed, 17.2 knots. The maximum results were: I. H. P., 5,993; speed, 18 knots. This trial was at light draught. The estimated cost for the Amphion complete for sea is about $1,100,000.

CALYPSO—CALLIOPE.

Steel cruisers, built at Chatham and Portsmouth dock-yards, respectively; were laid down in 1881; were completed, the former in August, 1885, and the latter will shortly be ready for sea. They are sister ships in all respects; have a steel protective deck 1½ inches thick over machinery, are bark-rigged, 235 feet long, 44 feet 6 inches beam, and displace 2,770 tons, at a draught of 19 feet 11 inches. The batteries are four 6-inch 89 cwt. B. L., on sponsons; twelve 5-inch B. L. in broadside; four Nordenfeldt, two Gardner, and a supply of Whitehead torpedoes. The engines were designed for a speed of 13.75 knots, and 3,000 I. H. P. They are of the two-cylinder horizontal compound type, and drive one 2-bladed feathering screw The coal supply is 550 tons, and the complement 266 officers and men.

The Calypso on her trial, light, developed 3,202 I. H. P., and 14.9 knots; revolutions, 83.8.

The Calliope was tried for two hours, January, 1886, with forced draft, and developed a mean of 4,021 I. H. P.; steam pressure, 85 pounds; revolutions, 89; vacuum, 25 inches; mean speed, 15 knots; results which were considered very satisfactory. Their estimated cost, complete for sea, is about $900,000 each.

SCOUT.

This torpedo-cruiser had her steam trials during September, 1885, with very satisfactory results. The ship drew 10 feet 6 inches forward, 14 feet aft; the load-draught being 12 feet 6 inches and 14 feet 6 inches. The first trial was on September 21, when only natural draft was used in the fire-room. The mean of the results for four hours were: I. H. P., 2,136; speed, 16.26 knots; revolutions—starboard, 138.2, port, 137.15.

On September 23 the trial with forced draft was made, the draught of water being 10 feet 4 inches forward, 14 feet aft, when a mean I. H. P. of 3,352 was developed, giving a speed of 17.6 knots, with steam pressure of 113 pounds; revolutions, 152.

SURPRISE—ALACRITY.

Steel dispatch vessels laid down at Jarrow by Palmer in 1884, and launched—the Surprise, January 17, 1885, the Alacrity March, 1885. They were intended, one for an Admiralty yacht, the other for special dispatch service and tender, probably in the

Mediterranean; they are also intended for use as scouts in time of war, and for this purpose are fitted for mounting a battery of six 5-inch B. L., if desired; also rapid-firing and machine guns, and a supply of Whitehead torpedoes. The vital parts are protected by coal 7 to 9 feet thick, in bunkers both below and above the protective deck. This deck is of steel three-eighths inch thick, and extends fore and aft over the machinery, horizontal amidships, with inclined sides. The hull is divided into forty water-tight compartments by bulkheads, which also serve to stiffen and strengthen the ship. All the large hatches are surrounded by coffer-dams. The entire after part of the ship is reserved for passengers, and is handsomely fitted for that purpose. The commanding officer has his quarters aft, but the rest of the officers and crew are quartered forward. These vessels have a three-masted-schooner rig, a displacement of 1,400 tons, are 250 feet long, 32 feet 6 inches beam, and draw 14 feet of water. The twin screws are driven by two-cylinder horizontal compound engines, designed for a speed of 17 knots, and 3,000 I. H. P., with forced draft. The boilers are cylindrical, four in number, and weigh with water in them, together with the engines, 360 tons. The coal capacity is 400 tons. At the speed trial of the Surprise, with natural draft, the I. H. P. developed was 2,104, giving a speed of 16.49 knots, on a consumption of coal of 2.6 pounds per I. H. P. At the four hours' trial with forced draft, the results were even more satisfactory; the mean speed attained was 17.85 knots; I. H. P., 3,017.7; revolutions, 133; steam in boilers, 96.6 pounds; coal consumption, 2.78 pounds per I. H. P. At these trials the ship was drawing 11 feet 3 inches forward, 13 feet 2 inches aft, slightly less than her load draught, which is 12 and 14 feet.

The Alacrity, on her four hours' trial, with natural draft, in July, 1885, developed a mean of 2,157 I. H. P., with steam pressure in boilers of 92.6 pounds; vacuum, 26 inches; revolutions, 121; coal consumption, 2.1 pounds per I. H. P., a speed of 16.14 knots was attained. The four hours' forced-draft trial developed the following mean results: steam in boilers, 99.3 pounds; vacuum, 25.1; revolutions, 134.8; I. H. P. 3,173; coal consumption, 2.77 pounds per I. H. P., and a speed of 17.95 knots. At the trials the ship drew 10 feet 6 inches forward and 11 feet 2 inches aft.

Both of these ships are completing for sea. Their estimated cost complete for sea is about $400,000 each.

FRANCE.

SHIPS LAID DOWN.

TAGE.

The largest unarmored cruiser yet designed by any nation was laid down at Les Ateliers et Chantiers de la Loire in November, 1885. She is ship-rigged, and has a complete under-water curved steel protective deck, lightly armored bulkheads forward and abaft the battery, an armored steel conning tower, and armored hatch-ways, A belt of cellulose along the water-line and the subdivision of the hold and space above the protective deck into many water-tight compartments insure the stability and buoyancy of the ship in case of perforation at or below the water-line. The principal dimensions are: length 390 feet, beam 53 feet 8 inches, depth 36 feet, mean draught of water 22 feet 10 inches, displacement 7,045 tons. The motive power is to consist of two sets of independent 3-cylinder horizontal compound engines, driving twin screws, designed to develop 8,115 I. H. P. with natural draft, and 10,330 I. H. P. with forced draft, and a speed of 19 knots. The boilers are cylindrical, and will be placed in three groups of four each, the groups being entirely independent of each other. The total weight of engines and boilers, including water in the boilers, is limited to 1,764 tons. The armament will be six 6.3 inch (16 centimetre) B. L. on the upper deck, one in the bow, one in the stern, four on sponsons; ten 5.5-inch (14 centimetre) B. L. in broadside on gun-deck; three Hotchkiss rapid-fire 47 millimetre (1.85-inch) guns; twelve 37 millimetre (1.45 inch) Hotchkiss revolving cannon, and seven above-water tubes for discharging Whitehead torpedoes. The cost of hull and engines is estimated at $1,689,000, of which $730,000 is for engines and boilers.

AMIRAL CÉCILLE.

Is also a ship-rigged protected cruiser with great speed, but is considerably smaller than the Tage. Her principal dimensions are: length, 378 feet 11 inches; beam, 49 feet 2 inches; depth, 34 feet 8 inches; mean draught, 19 feet 8 inches; displacement, 5,766 tons. (For further information see p. 80.)

FORBIN—SURCOUF.

Two rapid protected steel cruisers, lately laid down, the former at Rochefort, the latter at Cherbourg, will be formidable additions to the new French fleet of cruising vessels of great speed. Their principal dimensions are: length, 311 feet 7 inches; beam, 30 feet 6 inches; depth, 26 feet; mean draught, 13 feet 11 inches; weight of hull, 817 tons; and displacement, 1,848 tons. The engines, driving twin screws, are expected to develop 6,000 I. H. P., with forced draft, and a speed of 19.5 knots. Their weight complete, with boilers filled, will be but 544 tons. The coal capacity is fixed at 200 tons, which, it is estimated, will be sufficient for steaming 2,400 miles at 10 knots. An under-water protective deck of steel extends from end to end, horizontal in the center, with sloped sides. There is also a steel splinter-deck over the engine and boiler space. Above the protective deck there is a complete belt of cellulose, or other similar material, to prevent the entrance of water, if the hull is pierced at or below the water-line. This belt is 31.5 inches thick, and is formed by a light steel bulkhead, built at that distance from the skin of ship.

The rig will be four-masted schooner, spreading 7,255.5 square feet of canvas.

The battery will be two 14 centimetre (5.51 inches) B. L. on the upper deck, three 47 millimetre rapid-fire guns on the poop and forecastle; four 37 millimetre Hotchkiss revolving-cannon on the rail, and five torpedo-launching tubes, two firing ahead, one astern, and one on each beam. A complement of 150 officers and men will be carried.

The light battery and small coal capacity indicate the sacrifice made to ~~spars~~ space.

Work on the armored ships Brennus and Charles Martel has been stopped, and the money intended for these is to be used for the construction of rapid cruisers and torpedo-boats.

VESSELS LAUNCHED.

FUSÉE—FLAMME—GRENADE—MITRAILLE.

These are armored gunboats of a smaller type than the "Achéron" class. They are built of iron and steel, have one signal-mast fitted, and are of the following dimensions: length, 50.3 metres (165 feet); beam, 9.94 metres (32 feet 7 inches); draught, 3.15 metres (10 feet 4 inches); displacement, 1,045 tons. A belt of steel armor 9.45 to 7.1 inches thick protects the entire water-line; at the top of the belt is a slightly-arched 2 inch steel protective deck, and in the bow is a barbette tower, armored with 4 inches of steel. A belt of cellulose above the protective deck, and the division of the body of the ship into many water-tight compartments, add to the buoyancy and stability. The entire weight of armor carried is 333 tons.

The Fusée was laid down at Cherbourg in 1882, and was launched May 7, 1884. The Flamme, at L'Orient, laid down at the same time, was launched August 29, 1885. The Grenade, laid down at the same time and place, is not yet launched, as also the Mitraille at Rochefort.

The estimated cost complete for sea is about $328,000 each.

(For armament, machinery, &c., see p. 89.)

ITALY.

VESSELS LAUNCHED.

ANDREA DORIA.

This powerful addition to the Italian fleet was launched at Spezia November 21, 1885, where she was commenced in 1883, and it is expected she will be brought well towards completion by the close of the current year. She is a sister ship of the Ruggiero di Lauria and the Francesco Morosini, having a length of 328 feet, beam 64 feet 11 inches, and a mean load draught of 24 feet 11 inches. The displacement is 10,045 tons, and the twin-screw compound vertical 3-cylinder engines are expected to develop 10,000 I. H. P., and a speed of 17 knots. The boilers are cylindrical, eight in number, and weigh, together with the engines, 1,207 tons. Eight hundred and fifty tons of coal will be carried, which it is expected will enable the ship to steam for three days at the maximum estimated speed. The armament will be four 17-inch (43 centimeter) 105-ton B. L. R., mounted in pairs on barbette platform carriages, placed in diagonally opposite corners of the citadel; 6-inch B. L. R. will also be mounted. A large number of rapid-firing guns, Hotchkiss revolving cannon, and light machine guns will be carried. A number of Whitehead or Schwartzkoppf torpedoes will be supplied, which may be discharged through five tubes, two being submerged and three above-water tubes. Two second-class torpedo-boats will be carried. The armor of steel consists of a belt about one-third the length of the ship, surmounted by a rectangular central citadel, which has its corners cut away to admit of fore-and-aft fire from the outboard gun of each pair. The thickness of the side armor is 17.72 inches, and of the bulkheads 15.75 inches. A steel protective deck 3 inches thick protects the under-water body of the ship, which is further protected by coal filling the cellular space between the protective deck and the next deck above. A steel deck, 2½ to 3 inches thick, covers all parts of the citadel except the barbettes.

ETNA—STROMBOLI—VESUVIO.

The first two of these steel-protected cruisers were launched during the past year, the first in October, 1885, at Castellamare, and the second in February, 1886, by Orlando Bros. at Leghorn. The last is building by the same firm, but is not yet launched. Their principal dimensions are: length, 283 feet 6 inches; beam, 43 feet; draught, 19 feet 3 inches; and displacement, 3,530 tons. Their engines, ordered in England, of Hawthorne, are by the terms of the contract to develop 7,700 I. H. P. with forced draft, and 5,500 I. H. P. with natural draft. They consist of two sets of two-cylinder, inclined, compound, direct-acting engines, driving twin screws, and are expected to produce a speed of 19 knots. The armaments will be two 10-inch 25-ton Armstrong B. L., in unarmored barbettes on the fore-and-aft line, at either extremity of the ship, and six 6-inch Armstrong B. L. in broadside, on sponsons, all protected by steel shields or hoods; eight rapid-fire or heavy machine guns, and ten Whitehead or Schwartzkopff torpedoes. For discharging the latter two submerged bow tubes and two above-water tubes on each broadside are fitted. The under-water body is protected by a complete curved steel protective deck 2 inches thick, and by the arrangement of coal-bunkers.

VESSELS LAID DOWN OR ORDERED TO BE LAID DOWN.

RE UMBERTO—SICILIA.

Steel barbette battle-ships, somewhat similar to the British "Admiral" class without the armor belt. The former was commenced at Castellamare towards the close of 1885, and is expected to be completed in 1889. The latter will be laid down at Venice in August, 1886. Their principal dimensions are: length, 400 feet; beam, 74 feet 9 inches; mean draught, 28 feet 7 inches; and displacement, 13,251 tons. The engines of the former have been ordered in England, from Maudslay, and will be of 19,500 I. H. P., which it is expected will develop a speed of 17 knots. Each ship will carry four 17-inch 106-ton B. L. R., mounted in pairs in two barbette towers on the fore-and-aft line, the armor on the barbettes being of steel, 18.9 inches thick. A battery of 6-inch B. L. R., a supply of rapid-fire and machine guns, and a number of torpedoes will also be carried. A complete steel protective deck 3½ inches thick protects the under-water body, for which extensive coal protection is also provided.

TRIPOLI—GOITO.

Rapid torpedo-cruisers, laid down at Castellamare during the past year. They are built of very light steel frames and plating, and resemble in outward appearance enlarged torpedo boats. Their principal dimensions are: length, 229 feet 6 inches; beam, 25 feet 10 inches; mean draught, 9 feet 6 inches, and displacement 741 tons. The engines of the first are by Penn & Co., of England, while those of the latter, from the same designs, are being built by an Italian firm. They are estimated to develop 4,200 I. H. P., and a speed of 22 knots. [Thought impracticable; about 20, probable speed.—Ed.] Three screws are driven by these engines, the shaft of one coming out underneath the keel at an angle of 8°, while the others are on either side, but further forward than usual. Their armaments will consist entirely of rapid-firing and machine guns.

FOLGORE—SAETTA.

Torpedo vessels of similar type and appearance to the Tripoli, but of about one half the displacement. They were both laid down at Castellamare during the past year, and are of the following dimensions: Length, 185 feet; beam, 20 feet 7 inches; mean draught, 6 feet 7 inches; displacement, 317 tons. Their engines, driving twin screws, are of the ordinary torpedo-boat type, and are intended to develop 2,800 I. H. P., and a speed of 22 knots. Those of the first are being built by Penn & Co., of England, and of the second by Guppy & Co., of Naples. An armament of rapid-firing and machine guns only will be carried.

These last four vessels will be completed during the latter half of 1886.

SARDEGNA.

A first-class armor-clad, of the same general type as the Re Umberto, was ordered, February, 1886. To be built at Spezia.

FIERAMOSCA.

A protected cruiser, sister to the Etna, was ordered to be built by the Orlando Bros., of Leghorn, on the same date as above.

Another of this class is to be commenced during the current year.

ARCHIMEDE—GALILEO.

Dispatch vessels of the Barbarigo type (a gun and dispatch vessel of 650 tons, built in 1879, armed with two 4.72-inch B. L. R., and five 3-inch B. L. R.), ordered, February, 1886, to be laid down at the royal dock-yard at Venice.

VOLTURNO—CURTATONE.

Cruising gun-vessels, ordered on the same date, to be constructed at the same place.

MONZAMBANO—MONTEBELLO.

Torpedo-cruisers of the "Tripoli" type, ordered at the same time, to be laid down at Spezia dock-yard.

In addition to the vessels mentioned, the budget for 1886–'87 provides for the construction of four gunboats, a number of torpedo-boats of both the sea-going and coast-guard classes, and several harbor vessels, tugs, &c.

The total amount of the budget for the current year is $15,500,800.

STEAM TRIALS.

ITALIA.

The steam trials, at full speed, of this vessel took place at Spezia in March, 1886, when a distance of 47.5 miles was traversed in two hours twenty minutes, or at the rate of 17.66 knots per hour. A maximum speed of 18 knots was reached, but it is reported that the engines did not develop the horse-power called for by the contract, 18,000 I. H. P.

GERMANY.

VESSELS LAUNCHED.

CHARLOTTE.

The most important addition to the German navy during the past year is the Charlotte, an unarmored cruiser of the latest type. She was laid down at the Government dock-yard at Wilhelmshaven in 1882, and was launched September 5, 1885. Steel is used throughout in her construction; wood sheathing, coppered, protecting the under-water body. The stem and stern posts are of bronze. The hull is divided into nine water-tight compartments. The principal dimensions are: length, 242 feet 8 inches; beam, 45 feet 11 inches; draught, 19 feet 8 inches; displacement, 3,360 tons. She is ship-rigged, carries a complement of 427 officers and men, and coal sufficient to steam 5,000 miles at 12 knots. The armament consists of eighteen 15-centimetre (5.9 inches) Krupp B. L., four of which are on sponsons on the spar-deck, the others in broadside on the gun-deck, a number of Hotchkiss revolving cannon, and a supply of Schwartzkopff or Whitehead torpedoes. The motive power consists of two sets of independent two-cylinder compound engines, driving a single hoisting-screw. The estimated I. H. P. is 3,000, which is expected to develop a maximum speed of 16 knots. The fire-rooms are fitted for forced draft. Steam is furnished by eight cylindrical boilers, placed in two sets.

NIXE.

A ship fitted with auxiliary steam power, was laid down at Dantzig 1883, launched 1885, and to be completed early in 1886. She is intended solely for the training of seamen, is ship-rigged, 1,750 tons displacement, 178 feet 4 inches long, 43 feet 4 inches beam. The engines are compound, of 700 I. H. P., driving one hoisting-screw. Ten guns and a complement of 309 officers and men will be carried.

A dispatch vessel, not yet named, is being built by contract at the Germania Works at Gaarden, near Keil. She is of a different design from the Blitz and Pfeil, but will have about the same displacement, 1,380 tons. Her length, however, will be 322 feet 8 inches, while the others are but 245 feet 1 inch. The engines are designed to develop 5,400 I. H. P., the others having but 2,700 I. H. P. The deck is of steel, curved to turtle-back shape, as in torpedo boats, to better deflect projectiles. She was commenced in 1885, and is not yet launched. The estimated cost of hull and engines is $476,000.

GERMANY.

During the past year there was laid down at the Government dock-yard at Dantzig a small, heavily-armed cruiser, to replace the cruiser Albatross. She will be of light draught, with a rather flat bottom, and is intended chiefly for colonial and river service. The principal dimensions are: length, 215 feet 10 inches; beam, 35 feet 1 inch; depth, 22 feet 11 inches; maximum draught, 15 feet; and displacement, 1,500 tons. The engines, of 2,400 I. H. P., are expected to develop a speed of 15 knots. The armament will be two 24-centimetre (9.45-inch) Krupp B. L., 32 calibers long, one in the bow and one in the stern; two 12.5-centimetre (4.92-inch) similar guns, two 8.8-centimetre (3.46-inch) Krupp B. L., four 47-millimeter Hotchkiss guns, and two broadside tubes for discharging torpedoes.

AUSTRIA.

VESSELS LAUNCHED.

PANTHER—LEOPARD.

Torpedo-cruisers, somewhat of the British "Scout" type; built, of steel, at Elswick by Armstrong & Co.; commenced in October, 1884, and launched—the former, June 13, 1885; the latter, September, 1885. They have an under-water, inclined, steel protective deck, covering the engines and boilers. The coal-bunkers extend around and over the same space, and additional protection is given to the machinery by steel hoods over the cylinders, above the protective deck.

The contract called for a speed of 17 knots, using natural draft; but this has been exceeded by the Panther, whose official trials were completed in December, 1885. The mean speed of six runs on the measured mile was found to be 17.6 knots. During the course of twenty-four hours' continuous steaming she ran 70.6 knots in four hours, or at the rate of 17.65 knots. At the end of this twenty-four hours' trial, and without entering port, the speed trial under forced draft was made on the measured mile, with the result that the mean of six runs gave a speed of 18.4 knots. After leaving England a maximum speed of 18.9 knots per hour was attained. During February, 1886, a speed trial was made between Trieste and Pola, the distance, 64 miles, being covered in three and one-third hours, or at the rate of 18.57 miles per hour.

(For further information, see pp. 86, 138.)

RUSSIA.

VESSELS LAID DOWN.

At St. Petersburg the keel of an armor-clad vessel of the Alexander II type was laid in November, 1885, by the Franco-Russian Ship-Building Company. She is to be of 8,440 tons displacement, 327 feet long, 67 feet beam, and 23 feet draught. A complete belt of compound armor 10 inches thick protects the water-line, and a curved steel deck 3 inches thick protects the under-water body of the ship. The proposed battery is eight 8-inch B. L., mounted in pairs in four barbette towers, one at either end of the ship and one each side, in the waist, ten 6-inch B. L. in broadside, a supply of Hotchkiss machine guns, and Whitehead torpedoes. The barbette towers are to be protected by 12 inches of compound armor. The engines are compound, and are designed to develop 8,000 I. H. P.

A similar vessel is building at the Admiralty Works at St. Petersburg, and another at the Baltic Works near the same place.

The keel of a large protected unarmored cruiser was laid the latter part of 1885 at St. Nazaire, France, by the "Chantiers et Ateliers de la Loire" for the Russian Government. She is to be built of steel, sheathed with wood, and coppered. A curved steel deck 2.36 inches thick protects the engines and boilers, and the cellular construction insures the stability in case of perforation at or below the water-line. For the same reason coffer dams are built about the hatches. The length of the ship is 351 feet 1 inch, beam 48 feet 6 inches, and the displacement 5,000 tons. The engines are to be of the triple expansion type, and are expected to develop great speed. A battery of 6.3-inch (16 centimetres) B. L. guns will be carried, as also a number of rapid-firing and Hotchkiss revolving guns, and a supply of Whitehead torpedoes.

ILJIN.

This vessel is a compromise between the torpedo-boat "chasers," or torpedo-catchers, of the British service and the smaller class of torpedo-cruisers (*croiseurs torpilleurs*) of the French navy. She was laid down in December, 1885, at the Baltic Works, St. Petersburg, and is designed to have a speed of about 20 knots. A complete steel deck, dipping down forward and aft, protects the under-water body of the vessel. The dimensions are: Length, 230 feet; beam, 24 feet; draught, 9 feet; displacement, 600 tons. An armament of twenty-four Hotchkiss 47-millimetre revolving cannon will be carried, eight in light sponson half-towers on the main deck, and the others on the upper deck and on the bridges. A number of Whitehead torpedoes will be carried, which may be discharged through seven under-water tubes. The single screw is driven by three-cylinder vertical inverted compound engines, estimated to develop 3,500 I. H. P. (See p. 88.)

VESSELS LAUNCHED.

VITIAS AND RINDA.

These steel-protected cruisers were built at St. Petersburg by the Franco-Russian Company, and were launched, the former in 1884, the latter in 1885. They are similar in all respects, are sheathed with wood and coppered, are bark-rigged, carry complements of 400 men, and are of the following dimensions: Length, 298 feet; beam, 45 feet; draught, 18 feet; displacement, 2,965 tons. The vital parts of the ships are protected by a curved steel deck 1½ inches thick, and by the arrangement of coal-bunkers, a speed of 15 knots is estimated to be developed by horizontal compound engines of 3,000 I. H. P. The armaments are ten 6-inch B. L., four of which are on sponsons, four 4.1-inch B. L., a supply of rapid-fire and machine guns, and a number of Whitehead torpedoes, which may be discharged through three tubes.

Provision is made for a supply of 700 tons of coal.

BOBR AND SIVOUTCH.

These heavily-armed gun vessels, of a new type, have been completed during the past year—the former in Finland, the latter in Sweden. They are brig-rigged, 949 tons displacement, 187 feet long, 35 feet beam, and 9 feet 6 inches draught of water. The battery carried is one 9-inch Aboukoff B. L. in the bow, one 6-inch B. L. in the stern, six 3.94-inch B. L. in broadside, one 57-millimetre rapid fire and four 37-millimetre Hotchkiss revolving cannon. The engines consist of two sets of the two-cylinder compound type, driving twin screws. The estimated I. H. P. is 1,000, which it was expected would develop a speed of 12 knots. The Bobr has developed 1215 I. H. P., and a speed of 12.9 knots. Two hundred and five tons of coal can be carried, and a complement of 169 officers and men. The cost complete is about $363,000 each.

SPAIN.

VESSELS BUILDING.

The armored ship building in France, by the "Société des Forges et Chantiers de la Méditerranée," begun in 1884, is expected to be completed in October, 1887. She is a barbette ship, somewhat of the type of the French Amiral Duperré. The water-line is protected by a complete steel belt 6 feet 11 inches wide, of which 2 feet is above the water-line. The thickness of this belt decreases from 17.72 inches at the water-line to 11.8 inches at the lower edge. The barbette towers are armored with 19.3 inches of steel. The tubes for the passage of ammunition and the conning tower are also armored. The hull is built of steel, has a double bottom, and is divided into 16 water-tight compartments. A complete steel protective deck shields the vital under-water parts of the ship. The principal dimensions are: Length, 344 feet 6 inches; beam, 66 feet 3 inches; draught, 24 feet 8 inches; displacement, 9,902 tons. The motive power consists of three-cylinder vertical inverted compound engines, designed to develop 7,000 I. H. P., with natural draft; they are also fitted for forced draft. The contract speed is 15 knots, maintained for six hours. The armament consists of two 12.6-inch 48-ton B. L. in the barbettes, two 11-inch 38-ton B. L. on armored sponsons, one each side, thirteen light B. L. guns in broadside, fourteen rapid-firing and machine guns, and six tubes for launching Whitehead torpedoes. The coal carried will be 600 tons, sufficient to steam 59 hours at full speed, or 180 hours at 13 knots.

ALFONSO XII—REINA CHRISTINA—REINA MERCEDES.

Unprotected iron cruisers, building at Government dock-yards, the first two at Ferrol, the last at Cartagena, will be completed during the present year. They are similar in all respects, the following being the principal dimensions: Length, 278 feet 9 inches; beam, 43 feet; draught, 21 feet; displacement, 3,090 tons. The engines are of the three-cylinder trunk type, driving one screw, and estimated to develop 4,800 I. H. P. with forced draft, and 3,400 I. H. P. with natural draft, and a maximum speed of 17.5 knots. The armaments are six 6.3-inch (16 centimetres) Hontoria B. L. on sponsons, protected by steel shields, a number of Hotchkiss machine guns, and six above-water tubes for discharging torpedoes. They will be bark-rigged, without royals, and will carry a sufficiency of coal to steam across the Atlantic at moderate speed.

INFANTA ISABEL—ISABEL II—DON ANTONIO ULLOA—DON JUAN DE AUSTRIA—CRISTOBAL COLON.

Unprotected cruisers of a smaller type, building at Government dock-yards. The first was launched at Carraca July 24, 1885, having been commenced in 1883. The principal dimensions are: Length, 209 feet 11 inches; beam, 31 feet 11 inches; mean draught, 12 feet 8 inches; displacement, 1,152 tons. The engines are designed to develop 1,600 I. H. P., and a speed of 15 knots is expected. Coal sufficient to steam across the Atlantic at a moderate speed will be carried.

The armament is five 4.72 inch (12 centimetres) Hontoria B. L., one on the forecastle, the others on sponsons, two each side, five rapid-firing or revolving guns, and two above-water torpedo tubes in the bow.

They will be brig-rigged and carry a crew of 173 officers and men.

FAST TORPEDO-BOAT CHASER.

A contract was given to the firm of Thompson & Co., of Glasgow, in November, 1885, for the construction of a torpedo-boat "chaser," of 350 tons displacement and 180 feet length; to have a speed of 22 knots and 3,000 I. H. P., developed by two sets of independent triple-expansion engines driving twin screws; three torpedo-tubes to be fitted, two in the bow and one in the stern, and an armament of one 3.5 inch (9 centimetre) Hontoria B. L. in the bow, four 6-pounder Hotchkiss rapid fire, and two Nordenfeldt machine guns to be carried. The boilers and engines are to be completely surrounded by coal, of which a sufficiency will be carried to steam 4,000 miles at 10 knots. Steel plating 1 inch thick protects the engine, and a steel bulkhead 1¾ inches thick across the vessel, in front of the boilers, protects them from a raking machine-gun fire.

THE FASTEST CRUISER YET DESIGNED.

After the difficulty arising from the Caroline Islands dispute, the Spanish Government decided to strengthen its fleet, and in its latest type of vessel ordered is to be found the most rapid and formidable cruiser yet designed. In beginning its work of naval reconstruction the Spanish admiralty invited designs and proposals for the building of one first-class cruiser of 4,300 tons displacement and two third-class cruisers of 1,000 tons. In competition were offered the designs of fifteen of the most eminent private ship-building firms of England and the Continent, and to J. and G. Thomson, of Clydebank, has been awarded the contract for building the 4,300-ton cruiser, their design and proposals having been accepted as the most satisfactory.

The following are the principal data of this vessel: Length between perpendiculars, 300 feet; breadth, molded, 50 feet; depth, molded, 31 feet 6 inches; draught of water, 20 feet; displacement, 4,300 tons; I. H. P. of engines, 11,000; speed under natural draft, 18.5 knots; under forced draft, 20.5 knots; coal capacity, 1,100 tons.

(For further information, see article on p. 83.)

CHINA.

TING YUEN AND CHEN YUEN.

These two armor-clads have been added to the Chinese fleet during the past year. Owing to political reasons they were not allowed to leave Germany, where they were built, until July, 1885, though they had been completed some time previously. They were commenced at the Vulcan Works, at Stettin, the former in 1880, the latter in February, 1881, were both launched the latter part of 1881, and completed in 1883. They are barbette battle-ships of 7,430 tons displacement, 296 feet 6 inches length, 59 feet beam, and 20 feet mean draught of water. The armor is compound, and is disposed on a central citadel 138 feet long, and a nearly elliptical barbette redoubt on the forward end of the citadel. The armor is 14 inches thick on the water-line, 8 inches at the lower edge, 5 feet below, and 10 inches at the upper edge, 8 feet 3 inches above. The redoubt is protected by 12 inches and the conning tower by 8 inches of armor.

The armament consists of four 12-inch (30.5 centimetre) Krupp B. L., mounted in pairs, *en echelon*, in the barbette redoubt; two 5.9 inch (15 centimetre) Krupp B. L., one forward and one aft, in machine gun-proof turrets; eleven Hotchkiss revolving cannon, and a supply of Whitehead torpedoes. The motive power consists of two sets of three-cylinder compound engines, driving twin screws, estimated to develop 6,200 I. H. P. and a speed of 14.5 knots. During the trials which took place before leaving Germany, the maximum results obtained were, for the first 7,200 I. H. P. and 15.38 knots, and for the second 7,300 I. H. P. and 15.5 knots speed.

They are brigantine rigged, have double bottoms, divided into 200 water-tight cells, the body of the ship being divided into twenty-three compartments, and a cork belt forward and abaft the citadel. A steel protective deck 2 inches thick, running down to the point of the ram, 11 feet below the water-line, and to the stern-post to cover the steering gear. The complement of officers and men is 300.

It is said these ships have proven very unsatisfactory to the Chinese Government since they have been turned over to its naval authorities.

TCHI YUEN.

A small-type battle and cruising ship of new design was also built at Stettin by the Vulcan Works, and was detained by the German Government for the same political reasons as in the case of the two battle-ships above described. She left Germany for China in July, 1885. Her dimensions are: Length, 236 feet 3 inches; beam, 34 feet 5 inches; draught, 15 feet 9 inches; displacement, 3,200 tons. A curved steel protective deck 4 inches thick, and 4 feet 9 inches below the water-line, protects the entire under-water body of the ship, which is further protected by coal, filling the space between this deck and the one above. There are two machine-gun-proof turrets on the fore and aft line, the base of the forward one being surmounted by a fixed tower, armored with 15-inch steel, which extends to a height sufficient to protect the base of the turret with its machinery and the gun carriages. The armament is two 8.27-inch (21 centimetre) Krupp B. L. in the forward turret, one 5.9-inch (15 centimetre) Krupp B. L. in after turret, two similar guns on the main deck aft, five Hotchkiss revolving cannon, and a supply of Whitehead torpedoes, discharged through four above-water tubes. The motive power consists of two sets of two-cylinder horizontal compound engines driving twin screws, developing 2,800 I. H. P. and a speed of 15 knots. One permanent mast is stepped aft, though two were fitted for the voyage to China. A crew of 180 men and a coal supply of 230 tons are carried.

Contracts have been made with Armstrong & Co. for the construction during this year of two large protected twin-screw cruisers of 5,500 I. H. P. each.

Two partially belted turret vessels, not yet named, were ordered in March, 1886, by the Chinese Government. The Vulcan Company, of Stettin, Germany, has the contract for building these vessels, which, for their size, will be very powerfully armed, and will be effective for either coast defense or distant sea service. Their principal dimensions are: length, 269 feet; beam, 39 feet 4 inches; depth, 25 feet 6 inches; mean draught, 16 feet 8 inches; and displacement, 2,900 tons. They will be built entirely of steel, with double bottoms extending two-thirds of the length, and the under-water body divided by bulkheads into 66 water-tight compartments. The armor protection is compound. It consists of a belt, 6 feet wide, extending the length of the machinery and boiler space, having a maximum thickness of 9.5 inches at and above the water-line and a minimum thickness of 5.1 inches. This belt will be terminated at either end by thwartship armored bulkheads 5.1 inches thick. At the forward end of the belt is a circular revolving turret 8 inches thick, on top of which is the conning tower with armor protection of 6 inches. The under-water body is protected by a complete steel protective deck 1.5 inches thick over the top of the belt, and 3 inches thick forward and abaft the belt. A partial cork belt above the protective deck gives additional stability. The engines, by the same firm, will consist of two sets of three-cylinder compound type, in two separate compartments, driving twin screws, and expected to develop 3,400 I. H. P. with forced draft. The boilers, four in number, will also be placed in two separate compartments. A speed of 15¼ knots with natural draft and 16 knots with forced draft is expected. Three hundred and twenty-five tons of coal will be carried, and a complement of 180 officers and men. The only spars will be one steel signal-mast with a military top.

The armament will consist of two 21-centimetre (8.27 inch) Krupp B. L., 35 calibers long, in the turret; two 15-centimetre (5.91 inch) similar guns mounted in recessed ports; two 47-millimetre Hotchkiss rapid-fire guns; five 37-millimetre H. R. C.; and four torpedo-discharging tubes, three of which are above water, and one in the bow below the water-line.

Magazine space will be fitted for 50 rounds of ammunition for each of the heavy guns, and 1,000 rounds for each machine gun.

Five boats will be carried, of which two will be fast steam pinnaces with torpedo outfits.

JAPAN.

UNEBI.

A bark-rigged, twin-screw, protected cruiser of 3,651 tons, laid down in 1884 at Havre by the "Société des Forges et Chantiers de la Mediterranée," and launched in April, 1886. She is built of steel, is 320 feet 10 inches long, 43 feet beam, 21 feet 6 inches draught of water. The speed guaranteed by the contract is 15 knots, with a development of 6,000 I. H. P. A steel protective deck 2.5 inches thick covers the machinery and magazines. The coal, of which a supply of 700 tons may be carried, is also arranged to give protection to the machinery. The armament is four 9.45-inch (24 centimetre) B. L. on sponsons, six 5.9-inch (15 centimetre) B. L. in broadside, one similar gun in pivot on the bow, twelve rapid-fire guns, two Nordenfeldt machine guns, and a supply of Whitehead torpedoes, dischargeable through four tubes. The Unebi is of the same size as the Naniwa, but of a French type.

KATSURAGI—YAMATO—MUSASHI.

Small, composite, bark-rigged cruisers, building at Government dock-yards, the Yamato at Kobe and the others at Yokosuka. The first two were launched March 31, 1885, and May 1, 1885, respectively, and it is intended to complete them during the present year. The dimensions are: Length, 208 feet; beam, 35 feet; draught, 15 feet; displacement, 1,476. The engines are horizontal compound, designed to develop 1,600 I. H. P., which it is expected will produce a maximum speed of 14 knots. The armaments consist of two 6.7-inch (17 centimetre) Krupp B. L., five 4.72-inch (12 centimetre) Krupp B. L., together with a supply of machine guns and Whitehead torpedoes, one tube on each broadside being fitted for discharging the latter. A crew of 205 officers and men will be carried.

TAKAWO.

A cruiser of larger type building at Yokosuka dock-yard, intended to have 2,300 I. H. P.

NANIWA.

This vessel, which has been completed during the past year, and was described in General Information Series No. IV, has had two successful trial trips, with closed stokeholds and forced draft, the speed at both trials being in excess of the estimate.

The first trial was held in October, 1885, when the vessel was brought to her load draught by the distribution of water or other weights to compensate for the absence of the guns or equipments not on board. Two runs were made over a course of 9.6 nautical miles, with the following mean results: Steam pressure, port, 90.37 pounds, starboard, 89.4 pounds; vacuum, port, 21.64 inches; starboard, 23.03 inches; revolutions, port and starboard, 123.22; I. H. P., 7,370; speed, 18.775 knots.

The second trial occurred in December, 1885, the ship being at practically the same draught as at the first two runs, over the same course, with results as follows: Steam pressure, port, 89.5 pounds, starboard, 87.65 pounds; vacuum, port, 22.82 inches; starboard, 22.87 inches; revolutions, port, 121, starboard, 121.7; I. H. P., 7,650; speed, 18.903 knots.

During the first trial there was a light head wind and considerable swell, causing some pitching of the ship. At the second trial the wind and sea were inappreciable in their effect.

BRAZIL.

There was launched October 24, 1885, at Rio de Janeiro, a large protected cruiser not yet named. She is ship-rigged, is built of steel, sheathed with wood and copper, has a double bottom, and is divided by transverse and longitudinal bulkheads into 74 water-tight compartments. The dimensions are: length, 270 feet; beam, 47 feet 4 inches; mean draught, 18 feet 6 inches; displacement, 4,500 tons. The protective deck, 2 feet 6 inches below the water-line, is steel, 1.6 inches thick, and covers all the vital parts of the ship. The hatchways are armored, and have coffer-dams about them. Two sets of independent compound engines drive twin screws, and are estimated to develop 6,000 I. H. P. with natural draft, or 7,500 I. H. P. with forced draft, a maximum speed of 17.5 knots being expected. Seven hundred and fifty tons of coal will be carried, and a crew of 450 officers and men. The armament is to be four 8-inch Armstrong B. L., on sponsons, on spar deck; ten 6-inch 4-ton Armstrong B. L. on gun deck; four rapid-fire guns; six revolving cannon or machine-guns, and a supply of Whitehead torpedoes. One first-class torpedo-boat, 96 feet long, will also be carried.

VOYAGE OF AQUIDABAN FROM LISBON TO RIO DE JANEIRO.

The Aquidaban is fully described on page 82. After delivery to the Brazilian officers she proceeded to Rio. The voyage from Lisbon to Bahia, 3,600 miles, was made in thirteen days seventeen hours, and from Bahia to Rio, 750 miles, in two days twenty hours.

The following is a summary of the voyage:

Mean steam pressure, 75 pounds; revolutions per minute, 68.7; vacuum, 28 inches (?); actual speed per hour, 10.76 knots; coal per I. H. P. (1.366 kilos), 3 pounds, or about 40 to 45 tons a day.

ARGENTINE REPUBLIC.

There is building in England for this Government an armor-clad cruiser of 4,400 tons displacement, 249 feet 4 inches long, 49 feet 2 inches beam, and 20 feet mean draught of water. She is built of steel throughout, and has a central casemate, armored with 10 inches of compound armor. The armament will be eight 8-inch Armstrong B. L., and a large number of rapid fire or machine guns, together with a supply of Whitehead torpedoes. The rig will be brigantine, and the estimated speed is 14 knots.

PATAGONIA.

This unarmored steel cruiser is being built at Trieste. She is brig-rigged, and has the following dimensions: length, 213 feet 2 inches; beam, 32 feet 10 inches; draught, 12 feet 9 inches; displacement, 15.30 tons. The hull is sheathed with wood and coppered, and is divided into 70 water-tight compartments. An under-water curved steel deck, 1 inch thick, protects the under-water body. The general appearance is somewhat similar to the U. S. S. Atlanta, there being a high superstructure, extending to near the bow and stern. Forward of this superstructure is mounted one 10-inch 27½-ton Armstrong B. L. on a pivot carriage; abaft the superstructure, similarly mounted, is one 6-inch 5-ton Armstrong B. L., and in the waist are mounted two 6-inch 4-ton Armstrong B. L., on sponsons, one each side. On the superstructure four 4-inch 22-cwt. Armstrong B. L. are mounted in broadside; four Nordenfeldt and six Gardner guns are also mounted, two of them in the tops. The engines are compound horizontal, intended to develop 2,400 I. H. P. with natural draft and 3,000 I. H. P. with forced draft, with which a maximum speed of 14 knots is expected. Two hundred and sixty tons of coal will be carried.

SWEDEN.

SVEA.

This is a single-turret vessel now in course of construction at the Government dockyard at Stockholm, where she was commenced in 1885. Her length is 248 feet 4 inches; beam, 48 feet 7 inches; mean draught, 11 feet 10 inches; displacement, 2,900 tons. The central citadel is armored with steel 11.5 to 7.8 inches thick on the sides, which extend 3 feet above and 2 feet below the water-line, 12 to 11 inches on the forward bulkhead, and 11 to 8 inches on the after bulkhead. One revolving turret forward is armored with compound armor 11.5 to 9.6 inches thick. The under-water body of the ship is protected by a 2-inch iron deck, and is divided into numerous water-tight compartments. The armament will be two 10-inch Armstrong B. L. in the turret, four 9.84-inch Armstrong B. L., two 1.5-inch Nordenfeldt, four 1-inch Nordenfeldt, and a supply of Whitehead torpedoes. The engines are expected to develop 3,100 I. H. P. and a speed of 14 knots. There is one mast fitted with a military top to carry a machine gun. Sufficient coal to steam 850 miles at 12 knots will be carried. The complement is 150 officers and men. The total estimated cost of the ship complete is $775,000.

FREJA.

A steel unarmored cruiser, sheathed with wood, commenced by contract at Malmo December, 1884, and launched in 1885. The dimensions are: length, 215 feet 8 inches; beam, 40 feet; draught, 18 feet 8 inches; displacement, 2,000 tons. A speed of 12.5 knots is expected from engines of 2,000 I. H. P. The battery is four 5.9-inch (15 centimetre) B. L. on the upper deck on sponsons, eight 4.72-inch (12 centimetre) B. L. in broadside on gun-deck, four 1.5-inch Nordenfelt, two 1-inch Nordenfelt, two .47-inch Nordenfeldt. A crew of 250 officers and men will be carried. The estimated cost of the ship complete for sea is $420,000.

NORWAY.

GAR.

The only addition to the Norwegian navy is this gunboat, which was launched during 1885. She is built of steel, is of 278 tons displacement, 103 feet 4 inches long, 28 feet 2 inches beam, and 6 feet 11 inches draught of water. Compound vertical inverted engines of 450 I. H. P. develop a speed of 10 knots. The armament is one 10.2-inch (26 centimetre) B. L., two 37-millimetre Hotchkiss revolving cannon, and a supply of Whitehead torpedoes.

DENMARK.

IVER HVITFELDT.

The only vessel building for the Danish navy is this small armor-clad of 3,242 tons displacement, 252 feet 4 inches long, 44 feet 10 inches beam, and 17 feet 6 inches draught of water. She is a double-turreted vessel, with a central casemate. The armor on the hull and turrets is compound, 12 inches maximum thickness. A steel protective deck, 2 inches thick, flat between the turrets, and curved forward and aft, shields the vital portions of the ship. The battery is two 10.3-inch (26 centimetres) Krupp B. L. in turrets, and six 5-inch Krupp B. L. in casemate between turrets. A supply of machine guns and a number of Whitehead torpedoes are carried, the latter being discharged through four tubes. The twin screws are driven by two sets of two-cylinder compound engines of an estimated I. H. P. of 5,000, which, it is expected, will give a speed of 14.5 knots. The Iver Hvitfeldt was launched April 14, 1886.

J. C. COLWELL,
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MACHINERY.

THE TRIPLE-EXPANSION ENGINE.

During 1885, great progress was made in the development of the triple-expansion engine, the results obtained from merchant steamers fitted with them being such as to induce owners to put them in whenever practicable. The earlier engines of this type were converted from the two-cylinder compound by the introduction of a small cylinder over one of the larger ones; but, owing to the unequal pressure upon the crank-pins, this form has been almost entirely superseded by the three-crank engine, which, besides giving a uniform rotary motion, insures prompt handling of the engines, and makes it possible to run at very slow speeds when desirable. The cost per I. H. P. has been found to be about 1.6 pounds of coal per hour on a voyage, giving an economy of 20 per cent. over the ordinary compound engine of the same power. The pressure of steam is carried at from 100 to 180 pounds, the prevailing figure being 150 in nearly all recent engines built for merchant steamers.

In Great Britain, no less than sixty-two steamers were fitted with triple-expansion engines during the past year, and there are a number now in hand. The largest and most powerful single-screw engine of this type yet built is that for the North German Lloyd steamer Aller. The cylinders are 44, 70, and 108 inches in diameter, by 6 feet stroke, working with a boiler pressure of 150 pounds. On her recent trial, the engines developed 6,890 I. H. P., with a piston speed of 828 feet per minute. The consumption of coal was 1.4 pounds.

The following table gives the particulars of several twin-screw engines for the British navy:

	Renown and Sanspareil.	Nile and Trafalgar.	Aurora and Immortalité.	Serpent and Racoon.
I. H. P. of both engines	12,000	12,000	8,500	4,500
Diameter H. P. cylinder, inches..	38	43	36	26
Diameter I. P. cylinder, ...do...	58	62	51	37
Diameter L. P. cylinder, ...do...	88	96	78	57
Stroke ....do...	48	51	42	33
Boiler pressure................	130	135	130	140
Weight of machinery ....tons..	1,080	1,050	800	380
Estimated speed ....knots..	16½	16½	19	17

Besides these, there are building in Great Britain for the Russian Government three sets of engines of 2,000 I. H. P. each, and one set of twin-screw engines of 13,000 I. H. P.; and a contract was recently awarded for building the engines for the Italian ironclad Re Umberto, which are to be of 19,500 I. H. P.

In France, two large steamers built for La Compagnie Générale Transatlantique have tandem triple-expansion engines of the following dimensions: Diameter of one H. P. and of two I. P. cylinders, 49.2; of three L. P. cylinders, 74.8 inches; stroke, 66.9 inches. These engines are designed to be used either as triple-expansion, or as ordinary compound engines. One of these steamers, the Champagne, was tried recently, and her engines, working as ordinary compound, developed 9,500 I. H. P., the revolutions being 62. Working as triple-expansion engines, the revolutions were 59. The power was not given.

In Germany, nearly all the torpedo-boats built by Schichau for the German and Chinese Governments are fitted with this type of engine. The first-class boats have cylinders 21⅝, 34⅝, and 49½ inches in diameter, the stroke being 21⅜ inches, and the steam pressure 140 pounds.

Few triple-expansion engines have been built in this country, those built at the Goss Works, Bath, Me., for the Meteor, being the first. Since then Cramp has put them in two steamers, the yacht No. 246, and the Mascotte, now running between Tampa and Havana. Herreshoff recently built an experimental steam-launch fitted with this type of engine, which gave very satisfactory results on a trial witnessed by the Advisory Board.

The engines of the Parthia and Batavia are practical examples of the economy of the triple-expansion engine. In 1883, the Parthia, with her old compound engines, burned 47 tons of coal per day for a speed of 11 knots; in 1885–'86, her consumption for the same speed was 25 tons per day.′ For the Batavia, the figures were 40 for the compound and 21 for the triple-expansion engines.

QUADRUPLE-EXPANSION ENGINES.

Few quadruple-expansion engines have yet been built, the yacht Rionnag-na-Mara being the first one fitted with this type. She has a three-crank engine, with three cylinders of 7, one of 16, one of 22, and one of 34 inches diameter, with a stroke of piston of 24 inches. The following particulars of her three hours' trial are taken from Iron, April 2, 1886: Mean pressure of steam in boiler, 170 pounds; indicated horse-power, 412; coal, per I. H. P., 1.125 pounds; showing a saving of 40 per cent. over the best compound, and 17 per cent. over the best triple-expansion engines of similar size. The coal was weighed by Lloyd's engineer surveyor, the chief engineer of the steamer, and the representatives of the engine builders. Indicator cards were taken every half hour.

Denny Brothers recently launched the Jumna, a steamer of 5,200 tons displacement, which will be fitted with this type of engine, working with a boiler pressure of 160 pounds.

FORCED DRAFT.

The following table gives the indicated horse-power of the several ships with natural and with forced draft, and also the gain by use of forced draft.

Name of ship.	Grate surface.		Indicated horse-power.				Gain, using forced draft.
					Per square foot of grate.		
	Natural draft.	Forced draft.	Natural draft.	Forced draft.	Natural draft.	Forced draft.	
							Per cent.
Collingwood	756.0	756.0	8,100	9,558	10.71	12.64	18.0
Rodney	756.0	756.0	8,262	11,156	10.93	14.75	35.0
Howe	756.0	756.0	7,733	11,725	10.23	15.51	51.4
Conqueror	585.0	293.0	4,658	3,848	7.96	13.41	68.5
Leander	542.0	542.0	4,233	4,658	7.81	8.59	10.0
Heroine	110.0	55.0	1,127	702	10.25	12.8	24.9
Hyacinth	110.0	110.0	1,195	1,445	10.87	13.13	20.9
Satellite	110.0	82.5	1,116	1,397	10.15	16.9	66.5
Alacrity	218.5	218.5	2,157	3,173	9.87	14.52	47.0

Name of ship.	Grate surface.		Indicated horse-power.				Gain, using forced draft.
	Natural draft.	Forced draft.	Natural draft.	Forced draft.	Per square foot of grate.		
					Natural draft.	Forced draft.	
							Per cent.
Surprise	218. 5	218. 5	2, 104	3, 017	9. 63	13. 81	43. 4
Scout	207. 0	207. 0	2, 136	3, 352	10. 47	16. 43	56. 9
Curlew	135. 0	135. 0	906	1, 262	6. 71	9. 35	39. 3
Icarus	135. 0	135. 0	898	1, 236	....	....	37. 6
Foudroyant (*a*)	732. 0	732. 0	6, 016	8, 088	8. 22	11. 05	34. 4
Duperré (*a*)	730. 0	730. 0	6, 075	8, 010	8. 33	10. 99	31. 9
Vauban (*a*)	....	....	4, 137	4, 475	....	....	8. 17
Bayard (*a*)	416. 0	416. 0	3, 255	4, 064	7. 82	9. 67	24. 8
Niade (*a*)	340. 0	340. 0	2, 663	3, 215	7. 83	9. 46	20. 7
Iphigenie (*a*)	284. 0	284. 0	2, 230	2, 762	7. 85	9. 73	23. 8
Blitz	298. 5	298. 5	1, 794	2, 808	6. 01	9. 43	56. 4
Riachuelo	....	(*b*)	6, 926	7, 336	....	....	32. 4
Aquidaban	....	(*c*)	5, 270	6, 201	....	....	56. 9
Dolphin	270. 0	270. 0	1, 648	2, 253	6. 1	8. 35	36. 7

a The French I. H. P. = .9863 of the English. *b* Four-fifths power. *c* Three-fourths power.

R. S. GRIFFIN,
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ORDNANCE.

UNITED STATES.

The construction of new B. L. steel guns for the new cruisers has been continued under the direction of the Bureau of Ordnance, Navy Department, with but slight modifications of the original designs. The adoption of slower-burning powders has carried the pressure still further forward in the bore, resulting in the case of some foreign guns in their destruction. Happily no such accident has occurred in the United States with the Navy-built guns, but it has caused changes to be made in some of the minor details. The 8-inch guns for the Atlanta will have two additional chase-hoops, while those for the other ships will be hooped all the way to the muzzle.

SIX-INCH BREECH-LOADING GUNS.

All the 6-inch guns for the Chicago, Boston, and Atlanta are built on a design known as Mark II. But one gun of Mark I was built, which will be placed on board the Dolphin. The only difference in these two designs lies in the dimensions of the chamber, Mark I having a chamber of 7-inch diameter and Mark II 7½ inches. The length of the chamber in Mark II is a trifle shorter than that of Mark I, so that the capacity of the chamber remains the same in each. Mark II has also one more chase-hoop.

The proof of the Dolphin's gun was highly satisfactory.

The main points proven by the trial are as follows:

(1) That the gun will stand successfully as heavy a strain as 21.9 tons per square inch.

(2) That the Dupont brown powder is equal if not superior to any yet made, at home or abroad.

(3) The success of the gun (made of domestic steel) demonstrates our ability to design and manufacture guns as powerful as any yet known, while the excellent quality of its metal is fully equal to that of foreign make.

After the proof of No. 1 6-inch the star gauge indicated a slight enlargement of the chamber, the maximum being about .014 of an inch, while the slope connecting the chamber and rifled portion of the bore was somewhat scored. This scoring has been removed by lengthening the chamber slightly, which has removed all the blemishes, and the gun is now regarded in good condition for service, notwithstanding the excessive strains that it has passed through. As the service pressure for this design is not intended to exceed 15 tons per square inch it will be seen that so great a pressure as 21.9 tons would naturally produce the effects noted, and the fact that it has stood so well the severe tests to which it has been subjected reflects the highest credit upon the Bureau of Ordnance and affirms the practicability and propriety of building all guns necessary for the Navy under its direction.

The proof of No. 1 (the Dolphin's) gun was commenced in February, 1884, and during the time it was upon the ordnance proving grounds there were fired from it 271 rounds, with powder charges ranging from 25 to 58 pounds, while the weight of the projectiles was uniform at 100 pounds. After having satisfactorily tested the efficiency and power of the gun, the proof was continued for the selection of the powder best suited to it. That used in the first proof firing was the sphero-hexagonal powder, giving a velocity of 1,910 f. s. to a 100-pound projectile. Later, other brands of the same powder were tried and 1,927 f. s. was reached, but the pressure rose to 17.3 tons with the light charge of 45 pounds. Further trials with the same brand gave results as tabulated below:

Charge.	Projectile.	Muzzle velocity.	Pressure.
Pounds.	*Pounds.*	*Ft. per second.*	*Tons.*
40	100	1, 825	12. 8
43	100	1, 892	14. 8
45	100	1, 951	15. 4
46	100	1, 970	16. 2
47	100	1, 978	15. 9
44	100	1, 922	16. 1
45	100	1, 948	17. 2
46	100	1, 987	16. 4
45	100	1, 948	21. 9
48	100	2, 005	20. 9

While none of these pressures reached the dangerous limits, they were still much too great for service, and the German cocoa or brown powder was tried with the following results:

Charge.	Projectile.	Muzzle velocity.	Pressure.
Pounds.	*Pounds.*	*Ft. per second.*	*Tons.*
25	100	1, 277	5. 2
30	100	1, 406	6. 9
35	100	1, 555	8. 7
38	100	1, 624	9. 4
41	100	1, 705	10. 4
43	100	1, 773	11. 1
45	100	1, 808	11. 7
47	100	1. 836	12. 2
49	100	1, 890	12. 8

It will be observed that during the first series a velocity of 1,892 f. s. was obtained by a pressure of 14.8 tons, while in the second 1,890 f. s. was obtained with a pressure of only 12.8 tons, or a decrease of 2 tons for almost the same muzzle velocity. A second brand of the German powder was tried, but the results were not quite as satisfactory.

In October, 1884, the Dupont Powder Company entered the competition in the manufacture of slow-burning powder, and furnished the Bureau of Ordnance of the Navy Department with a sample lot, which was first tried on the 9th of October, 1884, and gave excellent results. Later, other samples, giving even more satisfactory results than those obtained from the first lot, were delivered, and this firm is now furnishing the Navy with a brown powder that is unexcelled. The grain is in the shape of a hexagonal prism with one perforation, the greatest diameter across the hexagonal face being 1½ inches, while the length from end to end of the prism is 1 inch, and the diameter of the perforation is three-eighths of an inch. The grains are arranged in the cartridge in a symmetrical manner so that the perforations form a continuous channel from end to end of the charge.

The best results obtained with this powder in the first 6-inch gun was in July, 1885, when a 100-pound projectile was thrown with a muzzle velocity of 2,011 f. s., while the pressure was but 14.3 tons with a powder charge of 50 pounds. Even this excellent result has been surpassed by the same firm with a 50-pound charge fired in one of the new 6-inch Mark II. On this occasion a muzzle velocity of 2,029 f. s. was given to a 100-pound projectile with but 13.3 tons pressure. This is the full service loading and will secure a velocity of 2,000 f. s., with a pressure well inside of what the gun will safely stand. Probably the highest velocity ever imparted to a 100-pound 6-inch projectile discharged from a 30-caliber gun was that obtained last March at the ordnance proving ground at Annapolis, when 54 pounds of Dupont brown powder gave a muzzle velocity of 2,105 f. s. with the light pressure of 15.2 tons.

As these guns will safely stand without injury as much as 23 tons per square inch for a limited number of rounds, it follows that a service velocity of over 2,100 feet could be safely used in cases of emergency.

With 2,000 f. s. muzzle velocity a 100-pound 6-inch projectile has a penetration in wrought iron of 12 inches, while with the best velocity, viz: 2,105 f. s., the penetration will be about 14 inches.

BREECH MECHANISM.

The new B. L. R. are fitted with a modification of the de Bange obturator.

The composition rings that protect the edges of the asbestos in the original design have been removed and steel disks substituted. The mushroom is held in place by a strong spiral spring surrounding the spindle. During the proof firing of No. 1 gun, the obturator occasionally stuck after discharge, so that the breech was opened with difficulty. To obviate this the spring will be replaced by frictionless rollers, composed of a number of small balls, working between shoulders on the spindle and plug. By the introduction of this improvement the plug can be turned easily and independently of the mushroom, while the thread on the plug acts as a lever to draw the mushroom bodily to the rear, and thus detach it from the sides of the chamber, rendering the opening of the breech an easy operation.

GUN MOUNTINGS.

The mountings for the new 6-inch B. L. R. as designed by the Bureau of Ordnance are constructed on the gravity return system. The recoil is controlled by a solid piston working in a cylinder filled with a mixture of glycerine and water. To check the recoil gradually, the ~~piston~~ cyl has slots cut in its interior surface, tapering from front to rear. By this means the liquid is allowed to flow past the piston in gradually decreasing quantities until it is almost entirely stopped. So successful has this system been applied in the new guns, that with the charge, namely, 50 pounds of powder and 100 pounds of projectile, the recoil of the gun does not exceed two feet. The slide for this mounting pivots in the port with a yoke. Some slight changes have been made in different carriages, but practically the mountings are all alike. It was found that the downward pressure of the breech when the gun was fired (especially with high elevations) was so severe as to endanger the elevating gear. To obviate this, a cone-shaped axle has been inserted in the cogged wheel working the elevating arm. This cone can be clamped by means of a screw. When clamped, it exerts sufficient friction upon the cogged wheel to cause it to turn with the axle, by the turning of which the elevating arm is moved and the gun elevated or depressed. When the gun is discharged, however, the sudden downward thrust turns slightly the cogged wheel on its axle, and thus the heavy and sudden strain on the elevating gear is overcome.

The 8-inch carriages, though constructed on somewhat the same general system, are arranged differently. The recoil cylinder in the 6-inch mounting is placed between the brackets of the slide, while in the 8-inch there are two cylinders which rest on the gun-slide, and on the top of which the trunnions are supported, so that the cylinders form part of the brackets of the top carriage, similar to the Vavasseur mounting. Both piston rods are secured to the forward end of the slide. The first of these carriages (built for the Chicago) was fitted with a pivoting yoke, but those to be placed in the ship will be on the central pivot pattern, the pivot bolt in this case being under the trunnions, or slightly in the front of the center of the slide, while those for the Boston and Atlanta will be pivoted directly in the center of the slide, that is, slightly abaft the trunnions when the gun is in the firing position. This latter type of carriage, though working in a smaller space, does not offer the same support for the gun as the former. An important modification will be made in the elevating gear of the 8-inch mountings. The main features of this plan are that all the working parts of the elevating system are on the slide, instead of on the carriage, by which slight changes in elevation can be made up to the moment of firing. This is accomplished by the introduction of small rails pivoted near the rear end of the slide, while the forward end is attached to the elevating gear. On this rail rests the breech of the gun, supported by a saddle, so that it has a free motion in or out. In the Boston and Atlanta the training will be accomplished by means of a steam engine placed on the orlop deck and connecting with the gun by a hollow shaft and gearing. The throttle being worked by a small rod in the center of the shaft.

GUN SHIELDS.

The mountings for the 6-inch guns are fitted with 2-inch steel shields, flat and standing at an angle of 40 degrees with the deck. It was intended to place this shield on the top carriage, but this arrangement has now been changed, and it is secured to the gun slide. The shields on the 8-inch mountings will be similar to those on the 6-inch, but will also have a 1-inch steel hood covering the after part of the gun and protecting the gun's crew. Late experiments at Annapolis have shown that these shields, inclined as they are, form a perfect protection against machine and rapid fire guns up to and including the 57-millimetre Hotchkiss, using the ordinary ogival-headed projectiles.

PROJECTILES.

The projectiles for present use with the new guns are all of cast iron, and do not differ much from those in service except in the method of taking the rifling, which is effected by a soft copper band forced on the rear end and finished in the lathe. Experiments have been made with steel projectiles. but they have not as yet been furnished to the service. A late patent rolled-steel projectile has given most excellent results, some made for the single-shot Hotchkiss having been fired several times through steel plates without any material change of shape.

SHIELD TESTS.

With the object of testing the resistance of the new steel shields, as fitted to the 8- and 6-inch mountings, and also to determine the amount of temper they should have, a series of experiments was conducted at the Naval Ordnance Proving Grounds, by direction of the Bureau of Ordnance.

Eleven 2-inch plates were prepared at the Chester Rolling Mills. These had varying degrees of temper, giving tensile strengths ranging from 60,000 to 107,000 pounds per square inch. They were placed at an angle of 40 degrees with the horizon, and fired at with armor-piercing projectiles from the 57- and 47-millimetre rapid-fire and 37-millimetre revolving Hotchkiss guns.

The velocities at impact were equal to the remaining velocities, due to the service charges at 1,000 yards, it being the intention of the experiments to simulate the fire of these guns at that range. They were as follows:

	F. S.
37-millimetre revolving gun	819
47-millimetre rapid-firing gun	1114
57-millimetre rapid-firing gun	1298

The effects produced on the plates therefore were identical with those that would be produced by shell fired with the full charges at plates 1,000 yards distant.

The results of temper were not very well shown, as the great majority of the eleven plates were indented to about the same degree. The hardest, however, showed much better resistance than any of the others, while in none did the heaviest projectiles penetrate deeper than 1 inch. The effects of 37-millimetre shot were practically nothing.

From the marks on the plates it appeared as though all the 47-millimetre, and some of the 57-millimetre, shot had broken on the instant of impact, separating the head from the cylindrical part, which bit deeper into the plate on account of its square edge.

A plate showing about the average amount of resistance was selected to further test the effect of several shot striking near the same point.

Three shots were fired from the 47-millimetre gun, at a point at which the greatest penetration had been made by previous shots from the 57-millimetre. The projectiles all struck close to each other, but the damage done was hardly more than would have been produced by a like number scattered about the plate.

The results of these trials demonstrate that a tempered steel plate, 2 inches thick, placed at an angle of 40 degrees with the horizon, affords ample protection against the heaviest Hotchkiss projectiles at a range of 1,000 yards, unless perchance two shot should strike in exactly the same spot, which would be of rare occurrence.

ZALINSKI'S PNEUMATIC GUN.

During the last year marked advance has been made in perfecting this peculiar piece of ordnance and the experiments are still being continued. So successful have they been that it now seems as though this system was soon to hold a prominent place in the ordnance of the day.

Experiments made at Annapolis threw so much doubt upon the supposed effect of dynamite when exploded against the side of a vessel that but little was expected from the pneumatic gun, even if it should be able to throw a shell any considerable distance. Lieutenant Zalinski, United States Army (to whom the credit of the present development of this weapon is due), claims that the experiments as carried on at Annapolis do not represent the exact state of affairs, and that while it is true that but little damage is done by exploding a charge of dynamite in simple contact with a plate, still that same charge when tamped will have great penetrating power, and again that the momentum of the shell must also exert a great power to assist the penetration. In support of this theory he has made two experiments. The first was to explode a charge of 8 ounces of dynamite against an iron plate ¾ inch thick, the charge simply touching the plate, while otherwise it was free to move in any direction. The result was only an indentation of the plate, thus repeating on a small scale the experiment at Annapolis. The second trial was similar in all respects except that over the charge was loosely placed a piece of angle iron open at both ends and large enough to span the cartridge without touching it. The result of exploding this charge was the perforation of the plate, the hole being much larger than the cartridge. This experiment was repeated with the same result when two plates were placed together, both plates having a large hole blown through them. It is claimed that these last experiments represent the true action of dynamite when exploded in a shell against the side of a ship, as the base of the shell acts as a tamping in the same manner, though much more efficiently than the angle iron.

The results obtained with the 2-inch gun are given in the table below:

Date.	Number of rounds.	Pressure.		Elevation.	Range.	Time of flight.	Remarks.
		Initial.	Final.				
1884.		*Pounds.*	*Pounds.*	° ′	*Yards.*	*Seconds.*	
Feb. 1	8	200	170	11 40	800	6.4	Eight struck in a space 8 by 6 feet; five were line shots; two lost, and the extreme variation on either side being 20 to 25 yards.
Feb. 3	11	250	180	9 39	800	5.65	
Feb. 25	17	438	....	24 54	2,000	14.3	
Feb. 26	10	450	....	25 00	2,000	14.5	Shell weighed 3.5 pounds. Six were line shots. One lost, variation 10 to 17 yards.

The results of these trials led to the construction of a 4-inch gun, which was only designed for experimental purposes and to furnish data on which to construct a larger and more complete gun. This piece was built in the spring of 1884, and mounted at Fort Hamilton in July of the same year.

The following table of the firing of this gun on December 3, 1884, contains all the main features of the trial:

Elevation.	Pressure.		Center of gravity from head of projectile.	Time of flight.	Range.	Remarks.
	Initial.	Final.				
° ′	*Pounds.*	*Pounds.*	*Inches.*	*Seconds.*	*Yards.*	
20 00	1,000	750	16	14.2	2,372	Weight of all projectiles, 20 pounds.
20 00	1,000	750	16	14.2	2,368	
20.05	1,000	750	16½	14.2	2,336	First three rounds were perfect line shots.
20 02	750	500	16½	13.0	2,076	
20 02	750	500	16½	13.4	2,068	Last shot, valve failed to work properly.
20 02	750	Lost.	16¾	12.6	2,026	

These trials show conclusively that shell containing violent explosives can be thrown with safety at least as far as 2,000 yards.

Experiments were then made to determine the best fuze for use with these shell. After numerous trials the electric fuze was adopted and so arranged as to ignite the charge from the rear end. This fuze detonates the charge on striking a rigid body, or on striking the water it acts only after complete submersion. In the development of this fuze the following interesting experiments were made:

An iron target, composed of plates about five-sixths of an inch thick, was used, the range being 60 yards.

A blank shell, containing sand to represent the charge and weighing 30 pounds, was fired through 2½ inches.

A similar shell, charged with dynamite, having no fuze, intended to explode on impact, was fired and only penetrated a single plate, the damage being actually less than that of the blank shell.

A third, fired with a detonating fuze in the point, did but little more mischief.

An electric fuze was then arranged so that the circuit should be closed when the body of the shell was one-eighth of an inch from the target, the primer being placed in the rear end of the charge. To further insure against premature explosion by simple contact a thin layer of cotton waste was placed in the front of the shell. The result of this shot was the most satisfactory of all, the six plates of the target (aggregating 4.5 inches) being broken through and indented in nearly a circular area of 18 inches diameter, while the stone wall in rear was somewhat broken. The charge fired in this case was 6 pounds of gelatine.

This last experiment would seem to prove the theory of Lieutenant Zalinski, that armor may be perforated without any penetration by the shell. But on the other hand may be mentioned some experiments which were originally intended to show that shell containing high explosives could be fired from an ordinary powder gun. They were not successful in the main, as the gun was finally destroyed before sufficient power was reached to propel a projectile a distance that would be of any practical value. However, shell were thrown at low velocities, some of which were directed against a heavy iron plate. Two shell, said to contain 7 pounds of dynamite, were exploded on the target. The first produced no appreciable damage, the second passed through an old hole and exploded against the backing, but did but little more damage than the first. A third shell, loaded with 8 pounds of dynamite, struck the edge of the backing and exploded, but did but little damage. These would seem to offset the experiments made with the pneumatic gun, but had the projectiles been fitted with the electric fuze as designed by Lieutenant Zalinski, the results might have been just the reverse.

In the winter of 1884 and '85 an 8-inch pneumatic gun was designed, and in August last it was completed and mounted at Fort Lafayette. This gun was intended to throw a shell containing 100 pounds of dynamite with an initial velocity about 1,490 f. s., while the mechanical details were such that one man could point and fire it without taking his eye off the sights. To accomplish this velocity a pressure of 2,000 pounds per square inch and a tube 60 feet in length were required.

The tube for this gun is composed of four lengths of tubing, five- eighths inch thick lined with a seamless brass tube one-eighth inch thick. The lining was not in the original design, and after boring the tube, fitting the brass, &c., the interior of the bore was $7\frac{15}{16}$ inches.

The barrel is supported on a truss suitably braced. The breech is closed by a simple gate which opens inward towards the valve. The entire system of the gun-barrel and truss turn on trunnions on the breech piece, which is of cast iron. The right trunnion is hollow and contains the firing-valve, which in general character is like that of the 4-inch gun. The trunnions rest in two hollow cast-iron uprights supported upon the gun-slide. By the use of compressed air and an ingenious arrangement of sheaves and wire rope the gun is easily pointed by one man without removing his eye from the sighting telescope. The air reservoir consists of eight tubes, 22 inches long and five-eighths inch thick, which are supported on the gun-slide and are connected through the trunnions with the firing-tube. The capacity of the air-reservoir is 140 cubic feet. The pressure is maintained by means of an engine in the fort, and conveyed through piping to the reservoir. Proper gauges indicate the pressure at all times.

This gun has been fired with a pressure of 1,000 pounds per square inch, with which a shell containing 60 pounds of explosive has been thrown $2\frac{1}{4}$ miles, the elevation of the piece on this occasion being 35°. With 33° elevation and the same pressure a shell containing 100 pounds of explosive has been thrown 3,000 yards.

It is the intention to rifle the bore and do away with the cumbersome tail-piece of the projectile. These changes will, it is supposed, increase both the range and accuracy of the fire.

It is to be regretted that experiments have not been made by firing shells containing 60 or 100 pounds of dynamite against a heavy armor plate and thus settle the important point of whether the pneumatic gun projectiles are armor-piercing or not. Even should it be shown that a 100-pound dynamite shell is not sufficient to crush heavy armor, still the gun would be most important in harbor defense, as it combines the advantages of mortars and submarine torpedoes, while its fire is more accurate than either. It is claimed that the chances of landing a shell from the pneumatic gun on the deck of a hostile ship is much greater than that of striking the side with a projectile from a high-powered gun. Again, the electric fuse of the dynamite projectile is arranged to detonate the charge after complete submersion so that a 100-pound shell striking within 21 feet from the side of a vessel has an equal or perhaps greater effect than a direct hit. The advantages of this system may be enumerated as follows:

(1) The ability to discharge safely, accurately, and with high velocity projectiles containing the most violent explosives.

(2) The accuracy of its fire surpasses that of mortars or any piece at high angles, where the force used is gunpowder.

(3) The effect of the explosion of 100 pounds of dynamite on or over the deck of a vessel would be more serious than that of the heaviest of powder-shell.

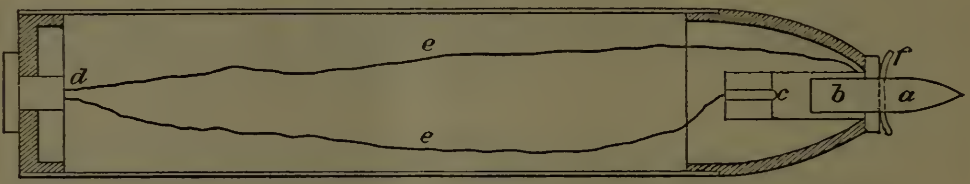
(4) That should the projectile fail to strike the vessel, but fall in the water within 21 feet of its hull it may yet act as a torpedo carrying 100 pounds of explosive.

(5) It may be used with great effect in clearing a channel of mines or other obstructions, as the electric fuze can be arranged to explode the charge on reaching the bottom.

ZALINSKI'S ELECTRIC FUZE.

Two forms of this fuze are made differing only in the methods of closing the circuit. The current is derived from a small battery composed of plates of zinc and silver, separated by a piece of cotton cloth that has been saturated in salt and water and dried, so that it is only necessary to moisten the fuze to make the battery active. In the first form, Fig. 1, *a* is a steel plunger carrying the battery *b*. This plunger is held in place by a copper pin, *f*, which gives way upon impact, when the pole of the battery *b* is driven in and closes the circuit by contact with C, the electric current passing through the primer *d* by means of the conducting-wires *e e*.

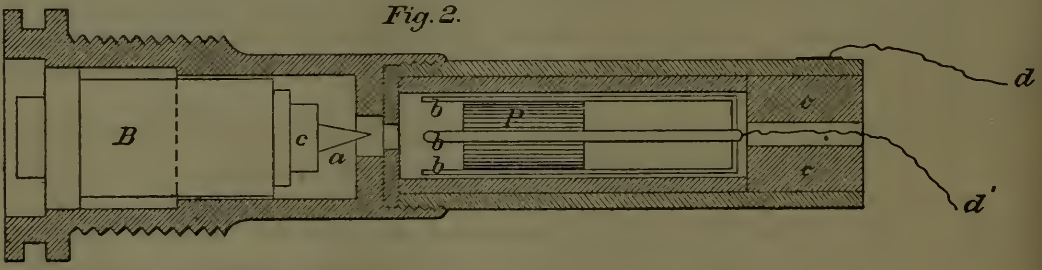
Fig. 1.



Shell as used in experiments against iron plates.

In Fig. 2, B is the chloride-of-silver battery. *c c c* is insulating vulcanite; *b b b*, metal springs holding the plunger P away from the pole *a* of the battery, until the shell carrying the fuze strikes a solid object, when the battery is driven in and the plunger P, by its momentum, strikes the point *a*, and thereby closes the circuit, the current pass-

Fig. 2.



Electric fuze arranged for powder guns or to cause explosions after submersion.

ing from the plunger through the metal springs *b* to the conducting-wire *d'*, and thence to the primer at the base of the charge, while the other branch of the current passes through the fuze-case to the conducting-wire *d*, and thence to the primer.

TWELVE-INCH BREECH-LOADING RIFLE (CAST IRON).

This gun, designed for the Army, was contracted for September 24, 1883, but was not cast until May, 1884, nor finished until April, 1885. The actual time required in its construction was ten months and twenty-five days. The breech-plug is of steel, and works in a steel bushing, thereby greatly increasing its power to resist the shock of discharge. The same general principles were observed in casting this piece as is customary with Rodman guns, viz, casting the piece hollow and cooling from the interior.

The first proof firing began on June 25, 1885, though five rounds had been fired by the founders before it was delivered to the Ordnance Board of the Army.

The last official record of the proof of this gun was dated September, 1885, when up to that time twenty-five rounds had been successfully fired. The heaviest charge was 265 pounds of Dupont brown powder with a conical shot weighing 800 pounds. Loaded in this manner the muzzle velocity was 1,705 f. s. with a pressure in the bore of 26,375 pounds per square inch. With the same powder charge but a lighter shell (750 pounds) this gun, elevated 6°, gave a range of 5,304 yards.

At the time of the last official report of the Chief of Ordnance, United States Army, the gun was still under trial, but it is doubtful if the performances given above will be exceeded. They may, however, be regarded as excellent for this class of gun but far behind what could be accomplished with an all-steel piece. In proof of which the following table is given, from which it will be seen that the heavy 12-inch Krupp is lighter by 6 tons while it has a penetration 4½ inches greater, and the light Krupp is 17 tons lighter and has a penetration about one inch greater:

Nature of gun.	At muzzle.				At 3,500 yards.	
	Total energy.	Penetration in iron.	Energy per pound of powder.	Relative weight of gun to energy of projectile.	Total energy.	Penetration in iron.
	Foot-tons.	*Inches.*	*Pounds.*	*Inches.*	*Foot-tons.*	*Inches.*
United States 12-inch B. L. R., cast iron, of 54 tons	16,197	21.24	61.0	33.0	9,372	16.25
Krupp's 12-inch B. L. R., steel, 37 tons	16,834	21.75	63.5	22.0	10,899	17.05
Krupp's 12-inch B. L. R., steel, 48 tons	23,905	25.75	67.2	20.1	15,644	20.75

PNEUMATIC GUN-CARRIAGE.

In July, 1884, Mr. J. A. Powlett, of New York, took out letters patent for a gun-mount using compressed air for performing all the necessary operations in directing and working heavy guns.

The inventor having shown that his system possessed desirable features, an experimental carriage was recommended by the Army ordnance authorities, and Congress, at its last session, appropriated the money necessary to construct and test the mounting. The carriage built under this appropriation was constructed at the South Boston Iron Works, and weighs 40 tons. It has lately been completed and sent to Sandy Hook, where the 54-ton B. L. R. was mounted on it for testing its powers.

In external appearance the carriage does not differ much from the ordinary pivot mounting in use in the Army.

When the gun is ready for firing the compressed air is admitted to the cylinders, in rear of the pistons. When the gun is fired the ports of the cylinders are automatically closed, the further compression of the air checking the recoil. The travel of the gun to the rear is nearly seven feet. After a recoil of five feet the compressed air is allowed to escape through a valve automatically opened, when the gun by its weight returns to the front end of the slide, being prevented from striking the front end too violently by means of compressed air admitted to the front end of the cylinder during recoil.

Elevation.—Elevation and depression are controlled by means of a cylinder which is secured to the breast-transom of the top carriage, the compressed air being conducted to it through a flexible pipe. The piston-rod of the cylinder has an end fitted as a geared rack, which engages a cogged wheel on the same shaft with another cogged wheel engaging the elevating arc of the gun.

Training.—An interesting feature of the invention is the training-gear, which is worked by a small pneumatic engine attached to the rear transom of the slide. It is composed of two oscillating cylinders whose piston-rods are connected to a crank on a shaft carrying a worm, which engages a worm wheel, and finally gears to the training trucks of the slide, they engaging a rack on deck.

The small steam-engine and air-pump for supplying the motive force is to be located on the lower deck of ships, or out of the reach of shot on shore, and the compressed air conveyed to the carriage through tubing.

Up to the 1st of December last the 54-ton cast-iron 12-inch B. L. R. mounted on this carriage had been fired in all fourteen times. Beginning with 100 pounds of powder and a 700-pound shot the loading was gradually increased to the full service charge of 265 pounds of powder and an 800-pound shot. The trial is not yet complete, nor has it been thus far entirely satisfactory, as might have been expected in the first carriage. The elevating and training gear did not act with sufficient exactness in the first preliminary tests. Improvements are being made, however, in the mechanical features so that the present weak points will be corrected.

It is claimed by the inventor that when the carriage is fitted with the late improvements the gun can be run in or out, loaded, pointed, and fired by three men, and that the gun has been run from end to end of the slide and elevated to a sight by one man in thirty-two seconds.

The preliminary tests indicate that the invention possesses merit. The final test of the carriage will probably take place during the coming summer.

ENGLAND.

Recent accidents in England with the new type of B. L. guns indicated the necessity of modifying to a certain extent their designs. A special committee was therefore formed, composed of the most prominent English authorities on gun construction. To this committee designs for strengthening existing B. L. guns, as well as those to be manufactured in the future, were submitted. The duties of the committee were outlined in three general questions, as follows:

I. Any alteration to the present method of treating steel for gun construction.

II. Any alteration to the present tests for steel, on which steel is passed into the service for gun manufacture.

III. Any alteration (*a*) in guns already made; (*b*) in guns in process of manufacture; (*c*) in guns for future manufacture.

Under these general heads the committee reported as follows (the report being made public in a Parliamentary return):

"RECOMMENDATION ON HEADING I.

(1) "All pieces forged in the tubular state should be annealed in that state before tempering.

(2) "All pieces forged in the solid state, with the object of being finally used in the tubular state, should be annealed in the tubular state before tempering.

(3) "The annealing to be effected by raising the temperature of the piece gradually, carefully, and uniformly to the highest point that can be applied without injuring the steel, and by cooling in a gradual and uniform manner.

(4) "After tempering, the piece is to be raised to a heat approaching that at which it was tempered, and reannealed by being allowed to cool slowly, as in recommendation No. 3.

"RECOMMENDATION UNDER HEADING II.

"The committee are of the opinion that 'Tests for steel' should remain unaltered. To test the soundness of the forgings, the committee recommend that the forgings themselves in a tubular state should be subjected to proof before they are used. This is done in France by means of a powder proof, charges of powder, tamped on both sides by projectiles, being exploded in the tube."

This method did not find favor with the committee, however, and in its place they recommend some kind of hydraulic percussion test, the particulars of which are to be intrusted to the superintendent of the Royal Gun Factory, and the chemist of the War Department.

REPLY TO HEADING III.

The committee consider that the use of slow burning powder will necessitate the strengthening of the chases of B. L. guns. They further recommend that each hoop should be as thin as possible consistent with economy, and that the required strength should be obtained by a greater number of hoops. With these objects in view, the committee made the following recommendations:

"16.25 *inch* (*steel*).—No alteration necessary in this design.

"13.5 *inch* (*steel*).—The guns at present under construction to be hooped to the muzzle. Those of future manufacture to be made on a design in which the chase is formed of a double tube, and having a thin line extending from the end of the powder-chamber to about half the length of the tube.

"12-*inch*.—Marks I and II (steel tubes and front coils, wrought-iron jacket and breech plug) to remain unaltered, but the charge of 295 pounds cocoa powder not to be exceeded.*

"Marks III and IV (steel) to be hooped to the muzzle. This will enable these guns to fire increased charges, if desired; they being of steel and of sufficient strength at the breech.

"Mark V (steel), for No Man's Fort, at present under construction, to be made on a design having the chase made of a double tube, or tube in two thicknesses.

"Guns for future construction to be made on a design with the chase formed of a double tube.

"10-*inch* (*steel*).—The five guns for Aden to be made on a design differing from former designs in the thickness of tube at the powder-chamber, also in its having the addition of a thin liner extending from the end of the powder-chamber to about half the length of the tube.

"Guns for future construction to be made on a design having the chase formed of a double tube.

"9.2-*inch*.—Marks I and II (steel tubes and wrought-iron jackets and breech-pieces) the chase to be hooped.

"Mark III (steel) for the Impérieuse, the chase to be hooped up to the muzzle.

"The sixteen guns (steel) for coaling stations to be completed on a design in which there is a liner extending from the rear end of the powder-chamber to about half the length of the tube.

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* See explosion of Collingwood's gun, p. 230.

"Guns for future construction to have the chase composed of a double tube and a liner, as above.

"8-*inch* (*steel*).—Marks I and II. There are only two guns of each of these marks made. These will be used for experiments and powder proof, and should be partially hooped on the chase.

"Marks III and IV. To be completed on designs differing from the former ones in having the chase strengthened by the addition of a B-tube, extending towards the muzzle. The preponderance is adjusted by a bronze sheath, which projects on the breech, forming a hood to protect the breech fittings.

"Guns of future construction to have the chase formed of a double tube.

"Marks II. Steel tube, wrought-iron jacket and breech-piece. These guns to have a hoop put on the chase when returned to the Royal Gun Factory. This will strengthen the chase and correct the present breech preponderance.

"Mark III (steel). To remain unaltered. Guns of future construction to have the jacket in one piece and the hoops carried to the muzzle.

"The experimental wire gun, which is now approaching completion, to be finished on a design having the chase reinforced with hoops and a counterbalancing jacket on the breech.

"5-*inch* (*steel*).—Marks I and II. To remain unaltered. Guns of future manufacture, as they might be used with increased charges of slower-burning powder, to be made on a design in which the hoops are brought more forward.

"4-*inch.*—Marks I (steel tube, wrought-iron jacket and breech-piece), II (steel), and III (steel), to remain unaltered, but guns of future manufacture to be made of steel and on a design suitable for increased charges of slower-burning powder.

New 12-*inch B. L. R. of steel, weight* 43 *tons.*—The loading for this piece has been placed at 295 pounds of cocoa powder and a projectile of 710 pounds. This gives 1,930 f. s. muzzle velocity and an energy of 18,470 foot tons, with the small pressure of 15 tons per square inch.

GUN TRIALS.

For the purpose of obtaining reliable data of the strength, power, and powder suited to the new 9.2 inch B. L. R. (designed for the battery of the Impérieuse and Warspite), a course of experimental firing was pursued under the direction of the English ordnance committee. The weight of the gun used for these trials was 22 tons, that of the projectile 380 pounds. The first rounds were fired for the purpose of ascertaining the most suitable quantity and class of powder for use with this pattern and caliber of gun, that is the powder which would produce the maximum muzzle velocity with a pressure in the chamber not to exceed 17½ tons per square inch. Previous experiments had pointed out the advantages of brown, or cocoa powders, and hence the larger portion of the experiments were confined to them, though some few rounds of black prismatic and "rifle large grain" were fired by way of comparison. The results of retarding the action of powder by moisture and other devices were closely observed, and from them the Government powder factory at Waltham Abbey has succeeded in producing a brown powder that has given most excellent results.

This powder, like the German cocoa, gives high velocities and but little smoke, while the pressures are moderate. There is, however, one disadvantage which seems to be peculiar to this brand; it is the presence of a liquid residue which collects in the chamber after each fire, and is so hot that it will ignite the powder even after it has been exposed to the air for some twenty or thirty seconds. It can be removed by careful sponging, but during the excitement of a rapid fire this may be neglected, when a premature explosion would probably follow. However, an accident of this kind could hardly follow from the greatest attainable speed with the larger calibers, as it would take all of thirty seconds to open the breech and put in the projectile, to say nothing of sponging, so that the dangerous period would elapse before the charge could be entered. Still this feature must be classed as a drawback to this brand of powder, as all the brown or cocoa powders possess it in some degree. The German cocoa being almost identical in this respect with the English brown, while the brown prismatic powder manufactured by Dupont also leaves a red deposit that is said to resemble sealing-wax, but it has not been observed in the United States that this deposit had sufficient heat to ignite gunpowder.

In relation to the gun itself, it was discovered that after one hundred and sixty-six rounds of full charges there was a permanent enlargement of the bore, which, though small, was enough to make it advisable to reline the gun; and it further appeared that all guns of this class have a tendency to enlargement of the bore after firing full charges. The increase, however, is infinitesimal, and no gun has been rendered unserviceable from it, but still it is sufficient to cause the restriction during peace to the use of reduced charges. With this precaution guns of this class should be able to stand about one thousand rounds, while it is doubted in England if more than two hundred rounds with full charges could be fired with safety.

These trials have resulted in fixing the weight of the projectile at 380 pounds, and that of the full charge at 170 pounds, the reduced or exercising charge at 80 pounds. With the maximum loading a muzzle velocity of 2014 f. s. is obtained.

GUN TRIALS ON H. M. S. IMPÉRIEUSE.

During the trials of the Impérieuse, the mountings of the 9.2-inch guns were also tested, and it was found that the least interval between fires was four minutes twenty-three seconds. These results were not regarded as satisfactory, and the loading arrangements are to be changed. Hand-power was used in working and loading the guns, but as a result of the late trials, it is understood that hydraulic loading gear will replace that originally fitted.

TRIALS OF THE ARMSTRONG 9.2-INCH B. L. R.

With the object of showing the power of penetration of the 9.2-inch B. L. R., manufactured by Armstrong, Mitchell & Co., for the armament of the Aquidaban, a Brazilian armored ship, the two following trials were made on the 17th and 18th of August last, at Ridsdale, England.

The details of the gun are as follows: Weight of gun, 21 tons; total length, 23 feet 11.3 inches; length of bore, 22 feet 3.8 inches; length of chamber, 3 feet 11.5 inches; rifling, uniform, spiral 1 turn in 28 calibers; weight of projectiles—common shell, 320 pounds; steel piercing shell, 390 pounds; maximum charge of cocoa prismatic powder, 210 pounds; initial velocity of 390-pound shell, with this powder charge, 2,080 f. s.; energy, (390-pound projectile) total, 11,700 foot-tons; per inch of circumference, 407 foot-tons; calculated thickness of wrought-iron that can be perforated with the above energy, 20.6 inches.

The gun was mounted on a hydraulic carriage.

The target used on the first trial, August 17, was composed of—

(1) Armor-plate of wrought-iron, 18 inches thick by 4 feet square on the face. Manufactured by Messrs. Cammell & Co., Sheffield.

(2) Backed by iron hoops made in two sections, the first having a length of 15 inches, and the second a length of 30 inches, both with a diameter of 46 inches; these hoops being partially filled with sand and laid horizontally against the plate.

(3) A second plate of 7 inches in thickness was placed at the other end of the hoops and secured to the first plate by long bars and nuts.

(4) A wooden backing of 12 inches supported by 12-inch piles and braces of iron.

(5) The whole covered by sand up to the face of the front plate.

The first round perforated the 18-inch plate passed through the hoops of sand and broke up against the rear or 7-inch plate. The head of the projectile was badly broken up, presenting longitudinal cracks.

On the 18th of August the Cammel plate was replaced by one specially made for this trial by Armstrong, Mitchell & Co. Against this plate (in which a flaw of about 1½ inches in depth and somewhat over a foot long was noticed) a second shot was fired with the same loading and with similar results. Both of these shots are shown in the following table which was prepared by Armstrong, Mitchell & Co.

Date.	Charge of cocoa powder.	Weight of steel piercing-shell.	Velocity per second.		Total energy.		Energy per inch of circumference.		Thickness of wrought-iron which can be perforated with this energy.	
			At muzzle of gun.	At face of plate.	At muzzle of gun.	At face of plate.	At muzzle of gun.	At face of plate.	At muzzle.	At target.
1885.	*Lbs.*	*Lbs.*	*Feet.*	*Feet.*	*Foot-tons.*	*Foot-tons.*	*Foot-tons*	*Foot-tons.*	*Inches.*	*Inches.*
Aug. 17 ...	230	390	2,179	2,167	12,840	12,699	447	442	21.6	21.5
Aug. 18...	230	392	2,178	2,166	12.894	12,782	449	444	21.6	21.5

TRIAL OF SIX-INCH ELSWICK GUN.

This gun is of steel, weighs 5 tons, and built on the hooped system, the weight of the projectile being 100 pounds. A modification of the breech-plug has been applied to this piece, consisting in a double instead of a single screw. This change, it is supposed, will make the plug more secure.

At the second round of the trial the firing attachment was blown out, but was recovered, and seven subsequent rounds fired without its giving any further trouble. It was said at Woolwich that a similar accident could not have happened to this attachment as fitted at that factory, but one equally if not more disastrous occurred at a late trial, when the axial vent-stopper broke, rendering the gun useless for some time, while the attachment of the Elswick gun, though picked up 200 yards to the rear, was uninjured. In explanation of the accident to the Woolwich gun, it should be said that the weight of the gun was 43 tons, and that its service charge is 295 pounds of brown powder, while at the time the accident occurred it was loaded with 265 pounds of black powder, a much more violent charge than was intended for the gun to fire. The damage was soon repaired, and the firing continued. The breech mechanism of the Elswick gun is much more complicated than that of the Woolwich, and requires to have the firing attachment adjusted after each discharge.

GUN EXPLOSION ON BOARD THE COLLINGWOOD.

On the 3d May H. M. S. Collingwood went out from Spithead to test the Vavasseur mountings of the after pair of 43-ton B. L. guns (Mark II). The proposed programme included six rounds from each gun; two with reduced charges of 221¼ pounds of cocoa powder, and four with full charges of 295 pounds. The projectile to be used with either charge was a common shell, filled with water, weighing 714 pounds. Scaling charges of 73¾ pounds were first fired, and the right gun fired with a reduced charge.

At the first round from the left gun (pointed off the starboard bow), charge 221¼ pounds, the muzzle was carried away about 5 to 7 feet from the end, and blown overboard. An examination showed that the gun burst at the point at which the hooping ended. It is reported that the muzzle separated from the body of the gun as if it had been cut, and that the forward part of the front hoop was injured. This is an experience similar to that of the French guns, mentioned on p. 234. The Collingwood gun is of the design known as Mark II; a steel tube, with wrought-iron jacket and steel hoops. The chase hoops were carried forward to within 5 to 7 feet of the muzzle. It had been previously tested on shore with higher charges than those fired.

For information concerning these guns, see report of Select Ordnance Committee, p. 227.

The right gun was fired, 60° abaft the starboard beam, at 7° elevation, and a range of nearly seven miles is said to have been attained.

When the left gun was fired there followed an unusual sound, and upon examination, as before stated, it was found that the end of the chase had blown overboard. The starboard side of the superstructure was blown in, the deck damaged, the glass work of the forward search-lights was smashed, and a machine-gun, mounted some 5 or 6 feet away, was shaken and broken.

The guns of the Collingwood are to be removed and replaced by those of Mark IV; all steel, hooped to the muzzle.

SECONDARY BATTERIES.

Following closely in the path of improvement in torpedoes and torpedo-boats is the progress made with machine and rapid firing guns as a means of defense against these small but dangerous foes. The secondary batteries of ships are becoming more important and efficient.

Many trials of the different systems of rapid firing and revolving guns have been made, but only two of this number are of sufficient importance to require special mention. The first was that of the secondary battery of the Polyphemus against a counterfeit attack by four torpedo-boats, while the second was made at Spezia to select the best system for the armament of the Italian naval vessels, and will be detailed under the head of Italian experiments.

The trial with the Polyphemus was for testing the power of her battery to destroy a torpedo-boat fleet before it could reach a dangerously close position. With this object in view four dummy torpedo-boats were prepared and anchored in the position that a like number would assume in making a genuine attack. The battery of the ship, to repel a movement of this kind, is composed of one 6-pounder Nordenfelt, one 6-pounder Hotchkiss, one 4-barrel 1-inch Nordenfelt, and several Gardner and Nordenfelt revolving guns of musket calibers. The ship took up a position 1,200 yards from the four dummies, and bringing them four points on the bow, shaped a course to pass them at 400 yards. Fire was opened at the beginning of the run and continued until the dummies were abeam 400 yards off, the ship during this time making 15 knots an hour. The dummies were struck many times, and it was decided that had they been torpedo-boats they would have been destroyed before being able to attain the object of attack, and, further, that with such a battery as is carried by this vessel it is possible to destroy a fleet of four boats at any distance inside of 1,000 yards. As the extreme range of the Whitehead is not over 600 yards, while its effective range cannot extend much beyond 400 yards, it follows that torpedo-boats, as now built, are no match for a well-selected secondary battery.

In this trial the Hotchkiss rapid-firing gun was adjudged the victor.

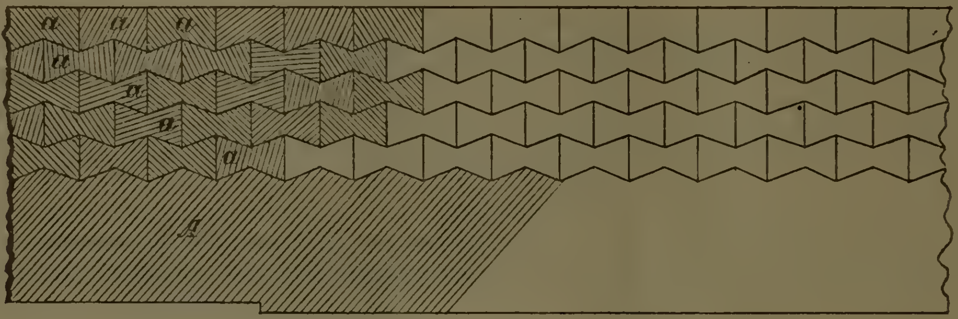
The damage from these light guns is local, and one shot from the larger caliber is more effective than many from the smaller, even though the latter be concentrated about the same point. Another great advantage of the larger calibers lies in the use of shell, which by treaty are not allowed to be used in calibers of one inch or less.

As a result of these trials the English Government has lately ordered as many as 200 Hotchkiss rapid-firing 3-pounder guns to replace the 4-barrel 1-inch Nordenfelt, which is to be withdrawn from service. The orders for 6-pounder guns is divided between the Hotchkiss and Nordenfelt firms, but the opinion of English naval officers seems to favor the Hotchkiss. The Hotchkiss system is also in favor in the United States and Italy, while France, Germany, Austria, Russia, Holland, and Denmark have adopted it to the exclusion of all others.

The growing disfavor of the Nordenfelt guns has lately been strengthened by a serious accident which occurred on the H. M. S. Albatross in April last. The meager and conflicting accounts that have thus far been made public do not admit of a detailed description, but it is believed that it was the result of defects in principle and is supposed to have been caused by the jamming of a cartridge. As two men were killed and three or four injured, it is thought wise to discard this system, and some of the leading English journals have expressed considerable indignation at the tardy action of the admiralty in removing the 1-inch 4-barrel Nordenfelt which they claim has been the cause of several serious accidents through its faulty construction.

WIRE-GUN CONSTRUCTION.

Among the numerous patents that have lately been obtained in England for the construction of ordnance is one of more than usual interest. This patent calls for the peculiar form of steel wire as represented in the accompanying figure, in which *a a a*, &c., are cross-sections. The tube marked A has a corrugated exterior on which the first layer of wire fits closely, while each succeeding layer forms also a corrugated surface for the next layer to fit into. The last layer having a flat surface, gives a smooth exterior to the gun.



By this patent great longitudinal as well as transverse strength is secured. No guns have as yet been constructed on this new system, but it is stated that the manufacture of an experimental gun will soon be commenced.

THE MAXIM AUTOMATIC GUN.

This remarkable piece of ordnance combines so many automatic motions that it literally charges and discharges itself, leaving only the duty of pointing to be done by those serving the gun. By the addition of improvements lately designed, the smoke will be consumed and even the sound of the discharge muffled. To put the gun in operation a belt containing the cartridges is placed over the magazine-wheel, when seven turns of the crank puts one cartridge in the chamber and fills the hopper-wheel with six others. It is only necessary now to pull the trigger, which fires the cartridge in the chamber; the recoil furnishes the power by which the mechanism extracts the empty case, puts in a new cartridge and fires it, and thus the operations are repeated until the belt is empty. The belts can be made to contain any number of rounds. Those for the light guns carry 333, and are simply two strips of canvas riveted together at regular intervals, the cartridges being placed in the spaces.

The length of the light rifle-caliber gun is 4½ feet over all. The working of this gun may be briefly described as follows: The gun-barrel has a motion backwards and forwards of seven-eighths of an inch, being moved this distance by the recoil. Beginning with the first discharge, the barrel in recoiling acts on a lever, which unlocks the breech-plug and carries it to rear, withdraws the empty case, and, revolving the hopper-wheel, brings a fresh cartridge in line with the bore. These motions all occur during the first half-revolution of the crank (which is attached by a connecting-rod to the breech-plug), the momentum of which completes the revolution, pushes the cartridge home, and fires it. Owing to some cartridges being a little weak, the second half-turn is assisted by a spiral spring attached to the breech-plug. The feeding is accomplished by two wheels which revolve in the same direction. On the circumference of these wheels, which are below the firing-gear, slots are cut of sufficient size to hold a cartridge. Over one of these wheels passes the belt containing the cartridges, while to rear and above is the second, or what may be called the hopper-wheel. Though these wheels do not contain the same number of slots (the first having ten and the second twelve), each motion of the breech-plug to the rear brings a slot of one in line with that of the other, and draws a cartridge from the belt into the hopper-wheel at the same time that the empty case is withdrawn from the breech, so that there are always six loaded cartridges in the hopper-wheel, until the supply is exhausted. In addition to the loading, firing, and feeding gear, there is a hydraulic attachment, by which the rate can be regulated so as to fire from three or four to six hundred shots per minute.

This light gun attracted so much attention and the inventor has received so much encouragement from the English Government, that a 3-pounder gun has been constructed for use in the English Navy. This gun is said to fire one hundred and fifty rounds per minute, with a muzzle velocity of 2,000 f. s. There is no water-jacket around the barrel of this gun as was fitted to the lighter caliber, and naturally the single barrel will heat rapidly under fire, but as the time that the gun could be of use in warding off an attack by torpedo-boats will be but a fraction of a minute, the gun will hardly heat dangerously in this interval. In the 3-pounder gun the feeding has been greatly simplified, as the belt containing the cartridges passes over the gun-barrel, so that the cartridges after being drawn from the belt fall in front of the breech-block, ready to be pushed into the bore. This arrangement is only practicable with the 3-pounder gun, from the fact that the weight of the cartridge insures a rapidity of fall sufficient to maintain a fire of one hundred and fifty shots per minute.

No trials of the 3-pounder gun have been made public, though the gun is being tested by the staff of H. M. S. Excellent.

GUNS BUILDING.

A recent Parliamentary return shows the following number of guns now being built for the English navy.

There are one thousand one hundred and seventy-three guns of all calibers now in course of construction, five hundred and seventy-seven being for armored, one hundred and nine for protected, and five hundred and seven for unprotected vessels. Of this number, five of 110 tons are being built by Armstrong & Co., eighteen of 66 tons by the Royal Gun Factory and the Armstrong or Whitworth firms, and the remainder, of small calibers and machine types, by the above-mentioned establishments or by the Nordenfelt, Hotchkiss, and Royal Enfield factories.

One hundred and eighty-two 5-ton guns are being made at the three establishments first mentioned; one hundred and seventy-seven 6-pounder rapid-firing guns by Nordenfeldt or Hotchkiss; and two hundred and sixty-four 3-pounder rapid-firing by Hotchkiss. In addition to these, there are three hundred and ten Nordenfelt, of 1 inch and less caliber, and fifty Gardner machine guns, in process of manufacture.

FRANCE.

The De Bange system still holds the most prominent place in construction of French ordnance, notwithstanding the many unfavorable comments that have lately appeared in print, caused mainly by the late accidents to some of the small calibers in use in the army. The latest gun constructed by Colonel De Bange is the 34-centimetre, for coast defense or shipboard. Some slight changes have been made in the details of construction since the last publication of this office. The main features of this gun are now as follows:

A tube of steel extends the entire length of the gun, upon which seventy-four hoops are shrunk. These are of steel and of the shape peculiar to this system: that is, they are of a less diameter in the center than at the ends, so that the different layers dovetail into each other, increasing thereby the longitudinal strength.

The first layer extends from end to end of the tube, and consists of thirty-two hoops. In the second layer are twenty-three hoops, extending from the breech end to about half the length of the chase. The third layer has sixteen hoops and covers the gun from the end of the breech to a little forward of the trunnions. Over the third series a short line of three hoops is shrunk on, covering the breech mechanism, also a trunnion and an elevating band. The last is not of sufficient size to add to the strength of the gun.

The general dimensions are as follows:

Caliber	34 centimetres (13.39 inches).
Total length	11.06 metres (36.1 feet).
Length of bore	10.48 metres (30.8 calibers).
Length of chamber	2.8 metres (9.18 feet).
Diameter of chamber	34.7 centimetres (13.66 inches).
Length of rifling	7.68 metres, or 22.6 calibers.
Number of grooves	144
Depth of grooves	1.5 millimetres (0.059 inches).
Breadth of grooves	5 millimetres (0.196 inches).
Gaining twist	From 30 minutes to 7 degrees.
Weight of gun	37,500 kilograms (82,500 pounds, or 37 tons).
Preponderance	0
Weight of charge	180 to 200 kilograms (390 and 400 pounds).
Length of projectile	1.27 metres (3.74 calibers).
Weight of projectile	420 to 600 kilograms (924 and 1,320).
Elevation, extreme	33 degrees.
Depression, extreme	15 degrees.
Estimated muzzle velocity	650 metres (2,132 f. s.)
Estimated maximum range	18 kilometres (11.1 miles).

As yet no results of firing have been made public, but should the expectations be realized, this gun will be capable of better work per ton of gun than any of this caliber yet constructed.

ACCIDENTS.

Last year no less than four accidents occurred to the De Bange field guns, while one occurred the year before. These have been seized upon by the German military papers as a basis for numerous condemnatory articles of the De Bange system. On the other hand, the French papers have explained the causes of the supposed failures by saying that they were all caused by carelessness and not from any fault of construction. The guns, it seems, can be fired without the breech being completely closed, and as the accidents occurred during quick firing with blank cartridges, the crew in their haste neglected to lock the plug, and it was consequently blown to the rear. The French papers deny that any of these guns were injured, and say the fact that the system has been in use for eight years and that these are the first accidents that have occurred proves that the system is not a faulty one. The only De Bange gun that has given way under fire is one of 24 centimetres, that was not regarded as perfect in its construction, and was therefore selected for trial to destruction, and that its ultimate failure was looked for. However correct or incorrect these statements may be, they have had their effect in altering the design of the guns so that similar accidents cannot occur, as hereafter it will be possible to fire the gun only after the breech is closed and locked.

42-CENTIMETRE GUN.

The first of two guns of 42 centimetres (model of 1885) which was under trial at Ruelle, France, has given way near the muzzle. The entire chase, except 60 centimetres (23.6 inches), was strengthened by hoops, and this part was blown off during the proof firing, adding another example to prove the great necessity of hooping the chase all the way to the muzzle in guns using the slow-burning powders. The cost of this gun was between 300,000 and 400,000 francs, and it would have been economy to have hooped the chase completely. Notwithstanding the loss of the 60 centimetres, the gun is still serviceable and will be put in the turret intended for it, though its finished length has been decreased two calibers, viz, from 21 to 19.

This failure is attributed by the French authorities to the inferior quality of the Martin steel, of which the gun was built. It is claimed that this steel is hard and brittle, besides wanting in uniformity, not only in different pieces, but the individual forgings themselves do not exhibit the same qualities throughout.

"HOPE" FIVE-INCH GUN.

Since the last publication Colonel Hope has improved the efficiency of his 5-inch guns, so that with a 20-kilogram charge and a 30-kilogram shell he has obtained a muzzle velocity of 622 metres (2,040 feet) per second, the pressure being 3,616 kilograms per square centimetre (51,347 pounds per square inch). When the charge was increased to 21 kilograms the pressure rose to 3,988 kilograms per square centimetre, 56,629 pounds per square inch, and the muzzle velocity rose to 630 metres (2,067 feet) per second.

TESTS OF STEEL BATTERING SHELL.

11-*inch forged steel, St. Chamond and Krupp shell. Tested at Ochta, Russia, June* 11, 1885.

Two 11-inch steel battering shell, made at St. Chamond, were fired against a 15-inch iron Cammell plate, placed at an angle of 65° with the line of fire. And two of the same make and size were fired, in competition with two 11-inch Krupp shell, against a compound Cammell plate of the same thickness, placed normally to the line of fire. The distance of the targets from the muzzle of the gun was 352 feet.

The effect on the two St. Chamond shell fired against the iron plate was as follows:

The first one, weighing 549½ pounds, made a hole 10½ inches deep, 32 inches long in the line of fire, 14 inches in vertical diameter. It rebounded whole, but was deformed from near the base, the versine of the chord being .35 inch. The other, which weighed 550.4 pounds, also rebounded whole, being similarly deformed.

The compound plate was 12 feet high and 6 feet broad; it consisted of 10 inches of iron and 5 of steel. The results of the comparative tests were wholly in favor of the French shell.

The first St. Chamond projectile, weighing 552 pounds, went clear through the plate, breaking off the left upper corner. It was picked up to the left of the target, whole, but with eight small cracks at the front band, the largest of which was four inches long. The accounts fail to state the striking velocity with which this penetration was obtaine

The first Krupp shell, weighing 548 pounds, failed to pierce the plate; the cylindrical body fell back, leaving the head embedded. The succeeding shot made this head come out, and it was found that the penetration was 11½ inches. The plate had been struck in the center, and four radial cracks extended to the edges.

The second St. Chamond shell, of 548.6 pounds, penetrated the plate to the farther side, not going through, but rebounding, whole, with four cracks running the length of the head from the front band, and one in the cylinder. The point of impact was 20 inches from the lower edge, and the entire lower part of the plate was demolished.

The second Krupp shell, of 544.8 pounds, struck in a weak part of the plate, between two previously-made cracks; it penetrated to 6¾ inches, the cylinder falling back, leaving the head embedded. The steel part of the plate was partially separated from the iron, and four more cracks were opened.

As a result of these trials, the Russian Government ordered 1,400 shell of the type thus tested from the St. Chamond works.

34-*centimetre* (13.4-*inch*) *St. Chamond forged steel shell. Tested at Gâvre, June* 12, 1885.

The target was faced with a 15¾-inch iron plate placed at an angle of 70° to 72° with the line of fire, and the striking velocity aimed at was 50 to 80 feet greater than that necessary for normal perforation, which is 1,309 feet.

The shell were tempered as follows: first, brought to a cherry red throughout, plunged in oil, and kept immersed until cold; secondly, brought again to a cherry red, hung with the head, as far as front band, in cold water, kept so for 8 to 10 minutes, and then wholly immersed in oil until cold. They were weighted to 925.9 pounds.

The first shell was too hard for a file to touch on any part of the head. Striking velocity, 1,455 feet; angle with normal to plate, 18° 09′. It went through, grazed at 110 yards, and was recovered at 275 yards beyond the target. Two pieces of the plate were thrown 75 yards to the rear, one weighing about 220 pounds; another large piece was thrown 20 yards, and four other fragments were scattered among the frame work: the framing and backing were demolished in the vicinity of the blow, and the plate badly cracked. The projectile was found to be intact, without surface cracks within or without; it was set up 0.40 inch, and enlarged 0.14 inch in diameter. Four-fifths of the setting up occurred in the ogival head.

The head of the second shell was very hard to an inch beyond the band; in rear of that, while still hard, the surface could be touched with a file. Striking velocity 1,447 feet; angle with normal to plate, 18° 12′.

It went through the target, fell at 350 yards, rose point first, and ricocheted to 775 yards. The plate was broken, large pieces detached, and wide cracks opened.

The projectile was found to be slightly chipped on the head, and a longitudinal crack extended from an inch in front of the front band to the base; this crack penetrated through the wall of the shell, and the base-plug could not be unscrewed. The shell was set up 0.24 inch, and enlarged 0.1 inch; point distorted, 0.1 inch.

The lot was accepted.

19-*centimetre* (7.48-*inch*) *St. Chamond cast-steel shell. Tested at Le Bouchet, September* 11, 1885.

Four shots were fired, with striking velocities (computed) of 1,245, 1,248, 1,246, and 1,245 feet. The target, 262 feet from the muzzle, was faced with a 5.9-inch iron Marrell plate, 13 feet by 3.28, secured to 31 inches of wood backing. The shell were weighted to 158.7 pounds, and had been tempered as described above, the heads being kept five minutes in the cold water. The file indicated different and irregular degrees of hardness. The first went through, but broke up, the fracture showing a very fine, close grain. The others went through whole, being set up respectively 0.05, 0.07, 0.06 inch; points distorted, 0.06 to 0.08 inch.

The lot was accepted.

24-*centimetre* (9.45-*inch*) *St. Chamond cast-steel shell. Tested at Le Bouchet, December* 29, 1885.

The target was faced with a 9.84-inch wrought iron Marrell plate, with 31.5 inches of oak backing; distance from muzzle, 262 feet. Two shots were fired. Weights of projectiles respectively, 323.4 and 323.7 pounds; calculated striking velocities, 1,428 and 1,426 feet; angles of line of fire with normal to plate, 19° 30′ and 20°. The shell had been tempered as described above, the heads being kept between two and three minutes in the cold water. For six inches from the point they were too hard to be affected by a file; the very tip, however, was found to be less hard than the rest of the head.

Both shell passed clean through the plate without being cracked; the first was set up 0.15 inch, the second, 0.19 inch; points distorted, 0.24 and 0.19 inch.

The lot was accepted.

27-*centimetre* (10.6-*inch*) *St. Chamond forged steel shell. Tested at Gâvre, February* 12, 1885.

Only one shell had to be fired, the result being such as to authorize the acceptance of the lot. It was weighted to 476.2 pounds, and fired with a striking velocity of 1,525 feet, against a Creusot steel plate 9.84 inches thick, backed by 33 inches of wood. The plate had had the chill taken off; distance from muzzle, 320 feet; angle with line of fire, 90°.

The shell, on being tried with a file, was found to be perfectly hard on the surface of the head; in rear of the band the file affected the surface. It went through the plate and target, and buried itself deep in the earth at 550 yards beyond. On being recovered it was found to be intact, without a crack; it had been set up 0.47 inch in all, of which 0.39 had occurred in the ogival head; enlargement of diameter, 0.1 inch at the band, and 0.14 in the cylinder. The point was distorted 0.04 inch.

ITALY.

The Italian Admiralty have decided to put a large number of quick-fire guns on their men-of-war. Trials were made at Spezia, the following being offered for test: Hotchkiss, rapid-fire; improved Nordenfelt rapid-fire on recoil carriage; Armstrong rapid-fire; and a rapid-fire gun made at the Government Works at Venice. The Armstrong gun was not fired. The others were fired in the following order: Nordenfelt, Hotchkiss, and Italian.

The guns were mounted on board a small ship (the Vulcano) for firing at sea.

A large target was fixed on the breakwater in the middle of the harbor of Spezia, and two smaller targets of triangular shape had been anchored, one 550 inside and the other 550 yards outside the breakwater. The Vulcano then was placed 1,300 to 1,400 yards inside the breakwater and fire begun against the large target with the Nordenfeldt six-pounder gun, which was worked by Italian sailors. A first series of eighteen shots were fired in forty-seven seconds, for rapidity of fire with rough aiming. A second series of sixteen shots were fired in thirty-four seconds. The rapidity of fire with rough aiming and untried men was thus respectively at the rate of twenty-three and twenty-eight shots per minute. Afterwards, ten case-shots were fired with the gun almost level, in order to see how the lead bullets were spread over the range. Some of them were seen to touch the water 700 or 800 yards from the muzzle, and the whole range was well covered by the 150 lead bullets contained in each of the Nordenfeldt case-shot.

The second part of the programme consisted of the firing at three targets, respectively at 600, 1,200 and 1,800 yards, the ranges being only approximatively known, changing the aim at every third shot, and firing under difficulty, owing to the movement of the ship. Twenty-one common shell were fired, seven at each target, with good accuracy, and the shells on striking the water burst better at the shorter than at the longer ranges.

The firing at sea was closed with one more series of ten rounds fired rapidly in twenty-six seconds, in order to see if the gun would act well after being heated by the eighty-five rounds which had already been fired. Four of the last series were ring-shell, and burst on striking the water at the first impact, breaking into a larger number of pieces than the common shell. The Nordenfeldt gun was then mounted on shore for tests of penetration. The plates used were: (1) a 5½-inch solid wrought-iron: (2) a 4-inch solid (Cammell) steel plate; (3) one seven-eighths-inch steel plate, at an angle of 15° to line of fire. The two thick plates were backed by 10 inches of oak, and at right angles to line of fire, and 100 yards from the gun. The perforation was in every case complete, both with solid steel shot and chilled point shells, these latter bursting in the wood behind. The thin plate was then put at more acute angle to the line of fire, and only when this angle was 7° or 8° did the projectile fail to penetrate. The indicated muzzle velocity of this gun is 2,130 f. s., with a 6-pound projectile and charge of 2 pounds 15 ounces.

A few days afterward the Hotchkiss gun went through the same trials and programme. For rapidity forty rounds were fired, with rough aiming, in three minutes, the rate being 13.3 per minute. The shooting was good, but the men serving the gun complained of being fatigued by the shocks from the shoulder-piece. The muzzle-velocity was about 1,085 f. s., or about 300 feet below that of the Nordenfelt. Last of all the Italian gun was fired, but as it was designed for 1,480 f. s. velocity, it was not brought in direct competition with the other two guns in power. The rapidity of fire obtained, however, was about twenty rounds per minute, and both the mechanism and recoil-carriage worked well. (From Army and Navy Gazette, February 27, 1886.)

GERMANY.

KRUPP B. L. R. GUNS.

The four 100-ton Krupp guns built for Italy were tested in November last. The guns were fired singly and in pairs, with 2,000-pound shell and 772 pounds of powder. Both the guns and mountings gave most satisfactory results.

Nineteen-ton gun (9.45 inch caliber.)—This gun has lately been tested with the following results:

The trials began by firing a 215-kilogram (475 pounds) steel shell with the lighter charge of 68 kilograms (150 pounds). The range obtained by this fire with an elevation of 12° was 7,600 metres (8,310 yards). The same weight shell was afterwards fired with the heavier charge of 72 kilograms (155 pounds), when a range of 7,300 metres (7,983 yards) was obtained with 10° 30′ elevation.

With the lighter charge the muzzle velocity was 529 meters (1,735 feet) per second, while the heavier loading gave a velocity of 1,768 f. s. The pressures ranged from 2,220 atmospheres or 15 tons per square inch, for the light charge, to 2,625 atmospheres or 17.5 tons for the heavy charge.

The penetrations at the muzzle were, respectively, 20.4 and 21.6 inches of iron.

W. H. DRIGGS,
Lieutenant, U. S. N.

ARMOR.

The controversy existing between the adherents of compound and steel armor continues, and the rivalry for a general acknowledgment of superiority remains unabated. Each system has made considerable improvement in its details of manufacture, and the orders of foreign Governments for armor plates may be said to have been fairly divided between the two.

The English confidence in the compound plate remains unshaken, and the test-plates (10-inch) for the belted cruisers, made by Cammell & Co. and Brown & Co., as well as those for the Admiral Nachimoff (9-inch, Cammell), have certainly given most satisfactory results.

French plates recently manufactured by the Usines of St. Chamond and Marrel Frères have also given a capital showing under the firing-tests, although in these the energies on impact have been low.

On the other hand, the Italian Government, after most expensive and elaborate comparative tests, have decided in favor of the Creusot, or Schneider, all-steel plates, and have established a plant for its manfacture at Terni, near Rome, for supplying its new armored vessels.

The French use both the steel and compound plates; the Russians, compound; the Germans, compound; the Swedes and Danes use both.

Much better results have been obtained from the compound system since greater strength and rigidity have been given to the backing and fastening of the armor, and additional efficiency has also been gained by increasing the carbon in the steel face till it has reached 0.85, by improving the character of the iron back, and by subjecting the plates to hydraulic pressure or forging before passing them through the rolls. The ugly circular cracks peculiar to the compound plate are, however, noticeable in the recent test-plates.

The Creusot plate has also been improved since the Spezia trials in October and November, 1884. The second lot of plates for the Lepanto (made at Creusot) has recently been accepted by the Italian Government. It will be remembered that the tests for these plates were considered as unusually severe (see General Information, Series No. IV), and the satisfactory result of the trial indicates the great merit of this system of armor fabrication.

No comparative trials to determine the relative merits of these two systems of fabrication have taken place since those at Spezia, before referred to. In that series of tests the Creusot plate was shown to be greatly the superior, and while the compound plate has been improved since that time, it is equally certain that its rival has made quite as great advances.

The Creusot plate, victor in this important armor trial, is made of a homogeneous metal, is more easily and economically worked, and its market price is about one-tenth less than of the English compound plate. While the manipulation of the Creusot steel and plate remain a trade secret, it is generally supposed that the amount of carbon in the metal is about 0.45, and that the plate receives its strength and tenacity from the careful treatment of the steel, as well as from the forging and bending of the plate under the hammer or hydraulic press, and from its subsequent tempering and annealing. The balance of unprejudiced and disinterested opinion seems at present decidedly in favor of the all-steel plate as manufactured by Schneider & Cie, of Creusot. The St. Chamond-Marrel Frères works have recently made plates of *soft-*

steel backs and *hard-steel* faces, which they claim are superior to and more economical than the Creusot plate. The weld in these is said to be perfect. Firing-tests against plates of this system will be witnessed with the greatest interest, as such a combination of metal, if successfully effected, has been regarded as possessing the qualities of an ideal armor.

ENGLISH PLATES.

The armor-plates for the belted-cruiser class (English) are to be supplied by Cammell & Co. and Brown & Co., of Sheffield. The plates are made on their well-known compound systems, and were tested at Portsmouth in December and January last. The plates were 8 feet long by 6 feet wide by 10 inches thick (two-thirds iron). The gun used was the 18-ton 10-inch M. L. R.; charge, 70 pounds; projectile, 410–415 pounds (chilled iron); range, 10 yards; velocity, 1,364 feet.

The Brown plate received three shots. No shot got through; in fact the penetration was not great in any case, and the maximum bulge on back of plate 1.5 inches. After the third shot there was an ugly crack through the plate, and the usual circular cracks, peculiar to compound plates, were noticeable. The backing was uninjured. The plate withstood the firing remarkably well. The energy of shot on impact was 5,305 foot-tons.

The Cammell plate also received three shots. The energy on impact was 5,288 foot-tons. No shot got through; the heads of each remained fixed in the plate. The bulges on back of plate varied from 1.35 inches to 2.6 inches. The plate was badly cracked by the second and third shots. The backing was badly cracked in the neighborhood of last two shots.

The carbon in the steel face of this plate was 0.85 per cent.

The tests are said to have been considered as very satisfactory by the English officials, and must be so regarded from an examination of photographs of the plates.

Trial plates (*Cammell*) *for the Admiral Nachimoff, at Ochta, September* 5, 1885.

[First plate, 8′ × 7′ 6″ × 9″.]

First shot, from 9-inch B. L. R.: Projectile (cast-iron), 308 pounds; 1,343 f. s.; 3,490 foot-tons; powder, 60 pounds. [4,000][*]

Second shot, from 11-inch B. L. R.: Projectile (Krupp forged steel), 620 pounds; 1,250 f. s.; 5,792 foot-tons (normal); powder, 110 pounds.

Effects.—First shot simply splashed. Fine hair cracks and one circular crack. Second shot (loaded with pyroxoline) struck at angle of 15°. Clean hole through plate: stuck in backing. Plate shows very well after test.

[Second plate, same dimensions; three shots from 9-inch B. L. R.]

First shot: Krupp steel shell; 314 pounds; 1,478 f. s.; 4,080 foot-tons (normal); powder, 71.5 pounds; penetration, 7 inches.

Effects.—Projectile destroyed. Three heavy and several light radial cracks.

Second and third shots: Cast-iron projectiles; 308 pounds; 1,420 f. s.; 3,696 foot-tons (normal).

Effects.—One circular face-crack of considerable diameter.

Fourth shot, from Bruick 6-inch B. L. R.: Forged steel projectile; 97 pounds; 1,850 f. s.; 2,071 foot-tons; powder, 39 pounds; penetration, 9 inches.

Effects.—Projectile broke up. An ugly crack on plate near this last shot. Plate practically uninjured.

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[*] Energy considered proper for plate of this thickness, based on recent experiments at the naval proving grounds at Annapolis, in England, and Russsia, in which the plate, when properly supported, is expected to keep out the projectile.

FRENCH PLATES.

Compound (*St. Chamond*).

Compound plates manufactured by the works at St. Chamond for several French vessels have been tested at Gavre during the year. Photographs of these show, in most instances, remarkably good results, but in every test the lowness of the striking energy of the projectile is very noticeable. What the results of higher energies might have been is difficult to estimate.

Trial plate for the Flamme, December 23, 1885.

[Plate, 10′×2′ 8″×7″.]

Weight, 6,732 pounds; projectile (chilled iron), 97 pounds; 1,541 f. s.; 1,597 foot-tons; gun, 16-centimetre B. L. R. (6.3 inches); penetration, 3″.5 to 4″.7; number of shots, 3. [2,300]*

Effects.—Bad cracks through and through, both circular and radial. Bad bulge in back from first shot. The plate was extremely narrow and light.

Trial plate for the Styx, November 19, 1885.

[Plate, 7′ 5″×9′ 10″×7″.9.]

Weight, 23,492 pounds; projectile (chilled iron), 165 pounds; 1,436 f. s.; 2,362 foot-tons; powder, 32 pounds; gun, 19-centimetre B. L. R. (7.5 inches); penetration, not known; number of shots, 3. [3,000]*

Effects.—Very slight penetration. Bulges not great, though cracked in bulges of second and third shots. Remarkably good plate.

Trial plate for Requin, June 22, 1885.

[Plate, 10′ 10″×7′ 2″×13″ to 9″, mean, 11″.]

Weight, 32,934 pounds; projectile (chilled iron), 317 pounds; 1,355, 1,355, 1,427 f. s.; 4,035, 4,035, 4,639 foot-tons; powder, 75 pounds; gun, 24-centimeter B. L. R. (9.5 inches); penetration, 5.8, 4.5, 5.3 inches. (1st, 2d, and 3d shots.) [6,100]*

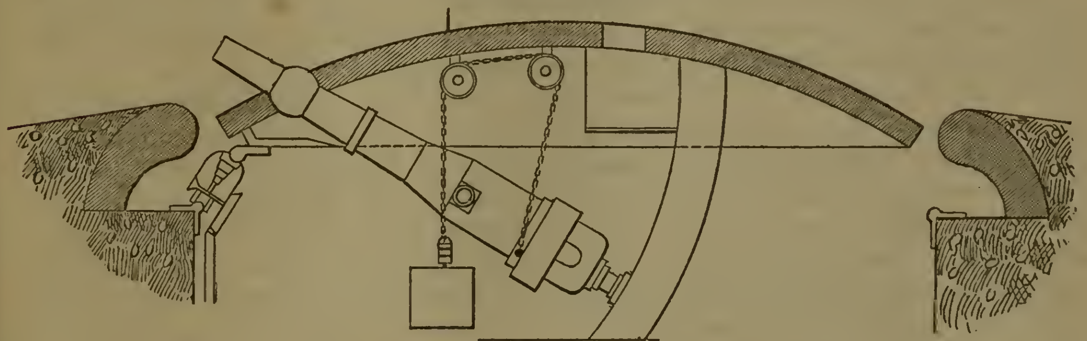
Effects.—Very few radial and no circular cracks. Back shows hardly any bulge, and but a few coarse hair cracks. Remarkably good plate; has the appearance of a steel plate after perforation.

THE BUCHAREST TURRET TEST.

Among the most interesting and instructive experiments that have been made lately are those at Bucharest for the object of determining the best turret for emplacement in the defenses of that city. For this purpose two turrets were submitted. One, a Grüson turret, designed by Major Schumann, a German officer, and built at the Buckau Works; the other, a Mougin turret, built by the St. Chamond Works.

The first of these was of the well known Grüson form; the second of a cylindrical shape, covered by a flat plate, 7 inches thick, weighing about 20 tons. For experimental purposes the Grüson turret was composed partly of wrought iron and partly of

Gruson Turret.



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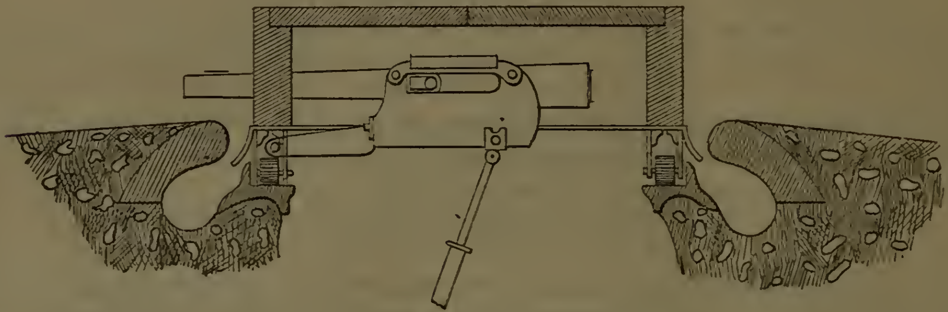
* Energy considered proper for plate of this thickness, based on recent experiments at the naval proving grounds at Annapolis, in England, and Russia, in which the plate, when properly supported, is expected to keep out the projectile.

compound plates, 8 inches thick, in six sectors, completing the sides of the mushroom, covered on top by two semicircular plates containing a manhole for directing the fire. In this turret were mounted two 6-inch Krupp guns on the peculiar non-recoil principle of Major Schumann. The turret rests on rollers on which it is revolved by rack and pinion gear.

The French turret differed widely from the German, both in material and design. It is cylindrical in form, and composed of three plates of rolled iron 18 inches thick, each weighing about 19 tons, resting on an iron structure containing the revolving gear.

Mougin Turret.



Both turrets were protected by an iron glacis. In the French were mounted two De Bange 6-inch guns. The Krupp guns mounted in the German turret were of about 3 tons weight, loading with a 70-pound projectile and a 20-pound charge, while those in the French turret weighed but 2½ tons, loading with an 88-pound projectile and 19 pounds of powder. (It will be seen that the guns were not high-powered.)

The trials began December 18, 1885: first, for testing the working of the guns and turrets; second, to determine the accuracy of their fire: third, the rapidity with which the fire could be maintained: and last, the effect of firing upon the turrets themselves.

From each turret were fired eighty rounds, of which twenty were fired at a target measuring 20 feet high by 33 feet long; range, 2,700 yards. In this practice the target was hit nine times by the French and fifteen times by the German guns. The latter fired once in six minutes, while the French fired every three and a half minutes, making a complete revolution after each fire. After these trials had been completed, each turret was subjected to attack by two 6-inch Krupp guns and one De Bange 6-inch gun at a range of 1,100 yards. This experiment was begun by firing at the French turret, twenty-nine steel shell from the Krupp and three from the De Bange gun. Forty-one projectiles were fired; thirty took effect upon the vertical part of the turret, the greater part of which were glancing blows, not penetrating deeply. Only two struck normally, penetrating about 9 inches. A salvo of three shots striking together near the joining of the plates dislodged a large piece and nearly perforated the turret. At the end of this pounding the guns and turret were in perfect working order, three rounds being fired from each gun as a test.

The Grüson turret was then attacked, the first fire being received on the compound plates. Out of twenty-seven rounds, thirteen shots struck. Six struck the front plate near the edge joining the one to the right and caused superficial hair cracks. The fire was continued on the 28th of the same month, when, out of a total of fifty-one rounds, there were twenty-one hits. Of all the shots that struck the turret thirteen were grouped close together on the joint before referred to. The effect of the last hits was to extend the cracks in the steel face and to dislodge part of it from the body of wrought iron. Like the French turret it was not materially injured, and fired successfully three rounds from each gun.

The two turrets were next subjected to the vertical fire of two 8-inch Krupp mortars, using cast iron and steel shell of 200 pounds weight, the range being 2,700 yards, and the elevation 35° and 55°. This fire began on the 29th of December, and was continued four days, during which time one hundred and sixty-five shells were fired, but no hits were made, though the practice is said to have been good, the shell falling in groups close to the turrets. The target was not large, being only 19 feet in diameter, but the experiment is of much importance, as it demonstrates the difficulty of landing shell on a turret of this kind, even with so accurate a piece as the rifled 8-inch mortar of Krupp, and with no distracting influences to spoil good practice.

To further test the resistance of the turrets, it was determined to move the firing battery to a range of 60 yards, but also to reduce the powder charge so as to give the same striking force to the projectiles as if the range had remained at 1,100 yards. It was deemed expedient to remove the guns from each turret, and here again the Gruson turret showed a superiority. Both guns were removed from it in six hours, while in the French a day and a half was required to accomplish the same work, part of the substructure having to be removed. This, of course, would be a great drawback in actual bombardment when it might be necessary to replace a disabled gun.

Four shots were fired at the French turret; the first struck on the edge of the left port and broke up, shattering the model gun which had been placed in the port; the other three struck in the neighborhood of the ports, giving a maximum penetration of 8 inches.

Seven shots were fired at the Grüson turret, but owing to its shape most of them were deflected, doing but little damage. These shot were received around the ports, where the armor was wrought iron.

The glacis armor of chilled cast iron was next attacked. The French armor withstood this test remarkably well, and established its superiority over the German metal, which was badly injured after the sixth round. The value of this system of protection for the mechanism of turrets was satisfactorily demonstrated.

As a final test, both turrets were tested to destruction by a direct breaching fire. The German turret was attacked on the compound plate, which had already received thirty hits and was partially damaged. Fifty projectiles in all were fired at this point, twenty-four of which took effect. By this fire a large piece of the steel layer of the compound plate was broken off, measuring 3 feet by 18 inches and 3 inches thick, but on the whole the turret stood the fire well. At the conclusion of the trial, when a grand total of one hundred and fifty-six rounds had been fired at this turret, sixty-nine of which took effect, it was pronounced by the umpires to be still in a serviceable condition, and capable of protecting its gunners and mechanism.

The armor of the French turret, owing to the perpendicularity of its faces, suffered more severely. Thirty-six hits out of forty-three rounds practically breached it. A large piece of plating was broken off, exposing the edge of the deck-plating, and a deep vertical crack was caused in the front armor. In all, this turret received sixty-two hits out of one hundred and eighteen shot fired at it. Not counting the piece broken off, the deepest penetration in its armor was 11 inches.

The guns were then replaced in both turrets; two days being required for this work in the case of the French, and less than one with the German. Even after the severe battering these turrets had sustained, both worked their guns perfectly, and many test rounds were fired.

An attempt was again made to land some shell on the roof of the turrets with the 8-inch mortar, but the result was no improvement on the first effort.

The commission appointed to decide on the respective merits of the two systems has not yet made known its findings. The advocates of each consequently claim the victory, and it must be acknowledged that each possesses desirable points of superiority.

The rapidity of fire of the French turret exceeded that of the German by 2½ minutes per round, and it was kept in constant motion, which made it almost impossible to concentrate the hits on any one point. But, on the other hand, the German turret is much more difficult to strike, owing to its lowness, and even those shot that hit were mostly deflected Sixty-two hits on the French turret were made in one hundred and eighteen rounds, some of which were fired at a distance of only 60 yards, while under the same conditions only sixty-nine hits were made out of one hundred and fifty-six rounds directed against the German turret. The bolts and rivets in the Grüson turret broke up badly, while the French structure stood hammering well.

One peculiar feature of the French turret is the method of pointing and firing the guns, which is automatic and electric. There are no sights either on the gun or turret, the firing being done by contact points, which are moved along a graduated arc inside the turret. The tower makes a complete revolution after each round, during which the gun is loaded, so that as the firing points come in contact the guns are automatically discharged. The direction and elevation of the guns are controlled by those outside the turret, and communicated to those inside by electricity. This plan would, of course, be only useful on shore, and of doubtful utility even there.

It is stated by the Gazette du Ministère des affaires étrangères: "* * * In consequence, we are informed that the Roumanian Government, having not yet constructed the forts at Bucharest, will not at present make any order, reserving to itself the right to profit by the improvements which may hereafter be introduced in the different forms of turrets."

TRIAL OF GRÜSON'S ARMOR AT SPEZIA.

The Italian Government having decided to erect two cupolas (armored turrets), each mounting two 120-ton Krupp guns, for the defense of Spezia, Herr Grüson was invited to construct them on his system, subject to certain conditions.

The conditions of the test were that the shield should receive three blows from the projectile of the 100-ton gun without portions of plate being dislodged from the interior face. The projectiles used were Krupp's steel shells, forged and hardened. The blow was the same as that which perforated or smashed the 18.9-inch plates of Schneider, Brown, and Cammell, in 1884. A test shield was erected at Spezia, and it received its first blow on April 20.

This experiment is as completely opposite in character to that made with the special Schumann-Grüson cupolas at Bucharest as can well be conceived. The latter was an attack of armor by comparatively small siege guns, whose fire was continued day after day from a short distance, and accurately directed. As pointed out in the Engineer of April 9, soft armor is specially suited to resist a regular breeching attack, and the structures were composed of wrought iron, although one had a hard steel face.

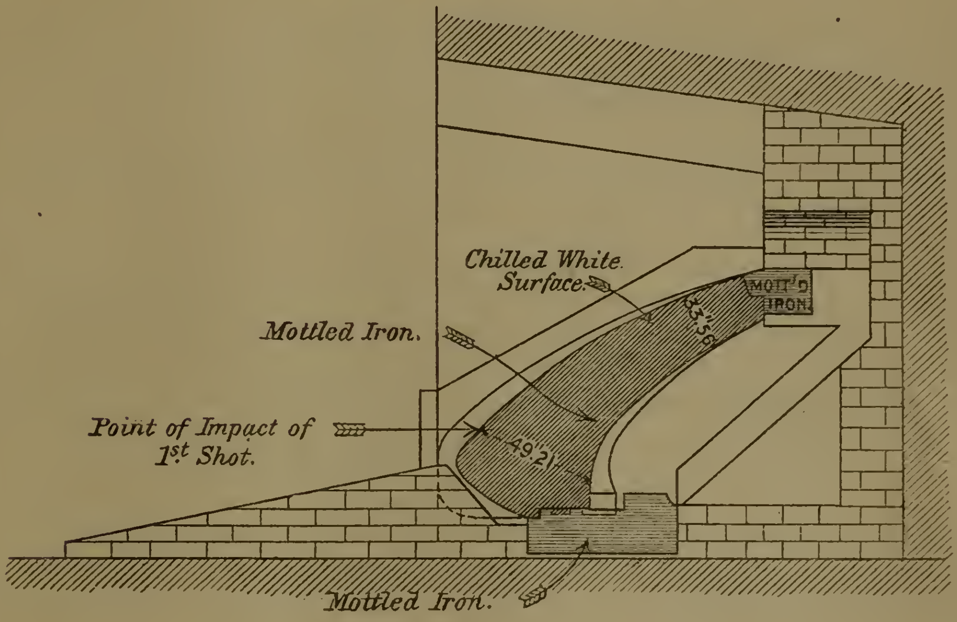
The exact opposite of all this may be said of this Spezia-Grüson trial. Coast forts must expect to be attacked by the heaviest guns existing, but it may be reasonably hoped that very few blows will be actually delivered on their sides, for there is little likelihood of a ship being able to remain opposite a fort many hours. The power to resist a few heavy blows is, therefore, what is called for. The power of Grüson's armor of chilled iron admirably supplies this.

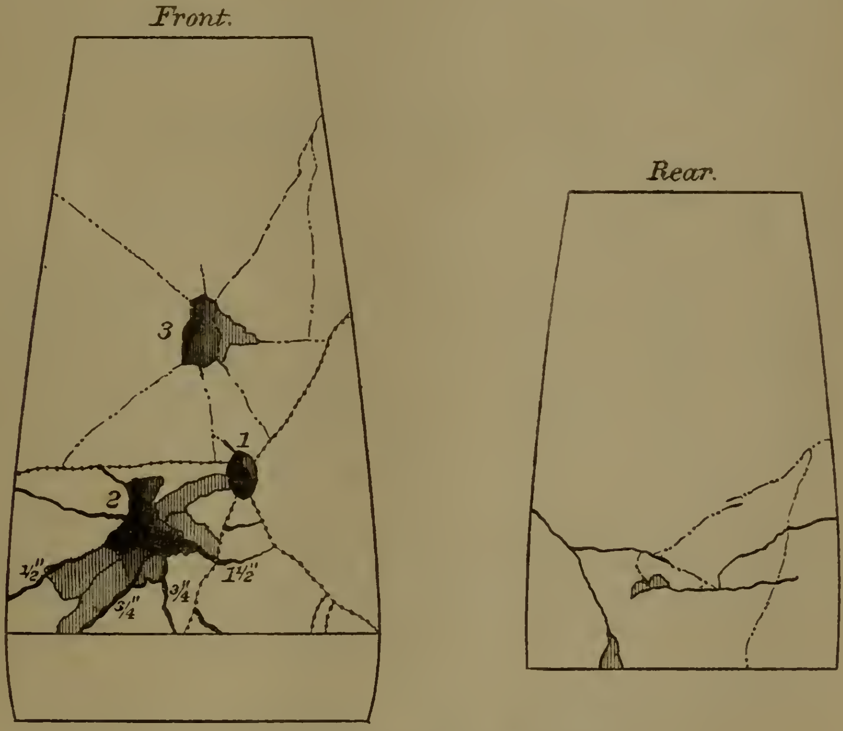
The shield used is of a peculiar shape, somewhat resembling a sector of a mushroom; its weight was 86.6 tons. The turret, when complete, will be composed of 15 similar plates; the total weight of armor will be some 1,378 tons. It will be supported on an iron ring worked by Elswick hydraulic machinery. The thickness of the shield, measured through the horizontal plane, at the top of glacis, is more than 60 inches; while the thickness of plate, measured normally to its inside curve at this point, is 49.2 inches, and 33.6 inches near its upper end. The shield is chilled white on its exterior face. The interior and other parts are of mottled iron. The trial plate was fixed between two cheeks of iron, properly supported by masonry.

The firing took place in St. Maria Bay, in the Gulf of Spezia, where the shield was erected facing the sea. The gun used was the 100-ton B. L., and is probably slightly more powerful than the Krupp 120-ton gun. It was fired from a raft afloat.

First round.—The shot struck somewhat the glacis and near the central line of the shield. The projectile broke into small fragments, which were thrown upwards. The angle of incidence was about 40°. The point did not hold, and a shallow scoop was made in the shield. Four cracks were made, and on the inside a fine crack was found.

GRUSON ARMOR.





Development of Surface.

Cracks of 1st Shot. ·-·-·-·-·-·-·-·-·-
" " 2d. " ————————
" " 3d. " —..—..—..—

The striking energy was 47.449 foot-tons; the weight of projectile 2,205 pounds; the striking velocity about 1,752 feet; the charge 827 pounds of Cologne prismatic-cocoa-powder; the range 145 yards.

Second round.—The second shot struck the shield a few inches to the right and above the first, with a velocity of 1,765 feet and an energy of 47.629 foot-tons. The projectile was broken into fragments, although one piece weighed as much as 56 pounds. The quality of the steel was excellent. The angle of incidence was 44°. The shot on this occasion made a more serious indent than before—about 4 inches; several cracks were made, some as wide as 1½ inches, and in some places the surface of the metal was chipped off. Up to this round any one might with impunity have remained behind the shield.

Third round.—The third round was fired on April 29, the firing conditions being as nearly as possible the same as those of the previous rounds. The energy of the projectile on striking was 47.306 foot-tons, and the mean pressure in the bore 13.11 tons per square inch. The charge in each round was made up in four cartridges ribbed longitudinally with serge rolls, so as to make the charge lie in the bore with a space around it. The crusher, gauger, primer, and obturator were of the Elswick types.

The second shot had somewhat shaken the masonry supports, so that some anxiety was felt as to the result of the third round upon the shield.

This was delivered on a spot close to the center vertical line of the shield, and about a meter from shot I. The angle of incidence being more oblique than before, the indent of the projectile was less, about 1½ inches. The projectile broke into small pieces, but the blow was sufficient to crack the shield, which is thinner at this point.

A portion of the plate, near the edge, was cracked through and separated from the rest of the shield so that it could be removed. In spite of this cracking and splitting, however, the shield appeared not only in condition to receive another, but was, in Herr Grüson's opinion, in better position than before to resist further firing.

Ballistic power of 100-*ton B. L. Armstrong gun fired at Spezia, April* 20, 24, *and* 29, 1886, *as given by London Engineer, May* 14.

Number of rounds.	First.	Second.	Third.
Velocity at muzzle in feet	1775. 6	1777. 9	1772. 0
Velocity at 278.9 feet in feet	1767. 1	1769. 4	1763. 5
Velocity at point of impact in feet	1762. 5	1764. 8	1758. 9
Energy at muzzle in foot-tons	48, 207	48, 326	48, 019
Energy at point of impact in foot-tons	47, 499	47, 629	47. 306
Energy per inch of circumference in tons	892. 8	896. 9	883. 6
Perforation in wrought iron on striking . . . inches	31. 2	31. 2	31. 1
Angle of incidence of projectile with tangent to shield . . . degrees	40	44	34½
Energy in foot-tons at impact per ton of shield	548. 9	550. 1	546. 4

The shield has shown wonderful powers of endurance and has withstood three most wonderful blows without any piece of importance being dislodged on the inside. Some small pieces (see shaded part on plate) which came off seem to have been shaken down rather than blown in, and a detachment of men behind the shield would have been uninjured.

The defensive power of the shield, which has received three shots from the most powerful gun in existence, is remarkable. (From London Engineer.)

TORPEDOES.

The development and improvement of auto-mobile and other movable torpedoes continue with great vigor: in fact, no other weapon of offense or defense receives at present so much attention. Many new patents of torpedoes have appeared during the last year, although few of them have been subjected to practical tests. Several of the older though undeveloped inventions have recently grown into greater prominence, but to-day the Whitehead or Schwartzkopff torpedo is the only one of value for naval purposes which forms a part of the equipment of any modern fighting ship, and is a commercial success. Indeed, the demand for this torpedo has so increased that it is now manufactured and supplied by several establishments in different European countries, and to such an extent has its purchase and use been stimulated that there is now no maritime nation which does not possess it, and few, if any, war vessels designed which are not intended to carry it in numbers (the United States alone excepted).

The Sims-Edison, Patrick, Paulsen, Brennan, and Berdan torpedoes have attracted some attention during the year. The first has been experimented with by a board of engineers of United States Army, and a small number of torpedoes of this system has been ordered by the Government, to be used in the harbor defense. The Berdan and Brennan torpedoes are adapted to harbor defense only. Interest in the Ericsson submarine gun has been somewhat revived by the purchase by the English Admiralty of a gun similar to that in the Destroyer.

Towing torpedoes are being discarded. By a recent order of the French minister of marine all vessels of the French navy are to turn their towing torpedoes into store at the first opportunity. The Whitehead will be the only torpedo in the French service except in torpedo-boats, where the spar-torpedo is also used.

The Howell torpedo has advanced greatly in the favorable opinion of naval officers, who see in it a worthy future competitor and rival of the Whitehead. While it is still at an early stage of its development, so far as its construction alone is concerned, it possesses inherent qualities not to be found in any other system, and bids fair to attain a speed which will make it a most formidable and valuable adjunct to the vessel carrying it. It is quite safe to assert that, considering the amount of money and labor yet spent upon it, it is now superior than was the Whitehead at a similar stage.

It is to be regretted that the Howell torpedo has not received more encouragement and assistance from this Government in its development. The invention has, however, it is to be hoped, made a considerable step in advance by the incorporation of a company which has been formed for its manufacture.

The Howell Torpedo Company, which owns the patents on this torpedo in the United States and foreign countries, was incorporated March, 1886, with a capital stock of $180,000.

The manufacture of these torpedoes has been begun near Providence, R. I. A sufficient number of exhibition trials will be completed by July 30.

The company at present offers the following guarantee to purchasers:

"To construct automatic torpedoes of a weight not to exceed 315 pounds, and to carry not less than 50 pounds of explosive.

"To have an effective submersion, and not to be deflected when launched in any direction from a vessel at full speed.

"To develop 340,000 foot-pounds of energy, and to have a speed of *at least* 19 knot for 200 yards, and a range of 400 yards.

"To attain these results under service conditions, from an effective launching apparatus, the torpedo being protected from machine-gun fire."

With suitable propellers the energy developed should give a higher speed than that guaranteed.

Should the terms of this guarantee be fulfilled, it is certain that, having in mind its small size and weight and performance, the Howell will be the most efficient torpedo yet produced for naval purposes.

The qualities of the Howell torpedo which particularly recommend it for naval purposes are, first, its small size and weight (8 feet 11 inches by 13.95 inches; weight, about 300 pounds); second, its great inherent directive force,* which makes it available for accurate broadside firing from vessels moving at high speeds and in rough water.

TORPEDO EXPERIMENT AT CHERBOURG.

In order to ascertain the effect of explosion of a torpedo upon a modern ship's bottom, the French minister of marine caused a portion of the old floating battery La Protectrice to be so fitted with inner bottom, bulkheads, and bunkers as to resemble the corresponding parts of vessels now under construction.

The Protectrice was built in 1864, of iron. She has a displacement of 1,287 tons, is armored with 5½ inches of iron, and has two horizontal engines, driving twin screws.

That part of the hull upon which the experiment was to be made was fitted with a double bottom and a longitudinal bulkhead, the latter about 6 feet inside the outer skin. Inside this bulkhead another was placed, for the purpose of preventing the admission of water to the engine or boiler rooms. The outer skin of the Protectrice is 0.51 inch thick. The inner skin 0.35, and the bulkhead 0.31 inch thick, were fitted for the experiment. (The bottom skin of a modern French armor-clad is about 0.70-inch iron plate.) The spaces between skins and bulkheads were empty.

The vessel was moored in the port of Cherbourg, about 800 meters from, and heading toward, the shore. The depth of water under the keel at high water was about 2 or 3 feet. Steam was raised upon the main boilers, and the engines were started before making the experiment. The fires and steam were so regulated that they might continue to run uniformly for some minutes. Two small propellers raised above the hull, in connection with the engines, indicated their action.

For purposes of economy a torpedo containing 51 pounds of gun-cotton, with 33 per cent. of water, was fixed to the bottom of the ship, 8.2 feet below the water-line, and abreast the boilers and engines, so that its explosion might represent in all respects that of a Whitehead torpedo upon striking a vessel in this vulnerable part. The charge used was thought to be the equivalent of 37.5 pounds of dry gun-cotton, and was adopted in view of the thin plating of the Protectrice, so that the effect upon it might be the same as that of the full charge of a Whitehead, 61.6 pounds, upon the plating of a modern armor-clad.

At 9 o'clock the ship was abandoned and the torpedo exploded. A column of water 20 meters high was thrown up on the side of the vessel, which gradually heeled to about 6 or 8 degrees. The regular motion of the indicators showed the engines to have suffered no serious derangement during the ten minutes following the explosion. After this time had elapsed the observers returned on board, and the engines continued to move for some minutes longer, when they were stopped and the ship hauled ashore. Up to the moment of thus touching the bottom no indication of the vessel sinking was apparent.

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* It will be remembered that the propellers of this torpedo are actuated by the power stored in the fly-wheel rotating in its longitudinal axis. When this fly-wheel (or the torpedo) is acted upon by a force which tends to cause it to turn about an axis not parallel to that of its rotation, there will be resultant motion about an axis perpendicular to the plane of the two axes first mentioned. Such a resultant motion will cause the torpedo to roll about its longitudinal axis, which brings into action the steering mechanism, by means of which the deflecting force is counteracted. As the deflecting cause and consequent rolling cease the steering mechanism becomes inoperative, but again acts upon the application of any other deflecting force.

At low water the ship was left high and dry, so that an examination of the hole caused by the explosion could be made. Its surface measured about 55 square feet, of a generally regular form (11.5 feet long by 4.6 feet high), with ragged edges, extending from the bilge upwards. The inner bottom skin was broken in, and many angle-irons were bent; but the longitudinal bulkhead (virtually the third skin, with which modern vessels are now built) is said to have withstood the explosion, although it was slightly cracked and two of its rivets were stripped.

Four live sheep were on board at the time of the explosion. They were apparently uninjured, save by a wetting from the column of water.

The vessel will be docked and a careful examination made. From the cursory inspection, the engines have received no injury, and the damage received is local.

This experiment is similar to that made by the Italians at Spezia, described in the last publication of this office.

THE WHITEHEAD TORPEDO.

The Whitehead or Schwartzkopff torpedoes continue to be in universal use (the United States excepted). This torpedo, in one form or another, is now manufactured in Austria, Germany, England, and France. Other maritime nations, and even those having factories of their own, as a rule purchase them of the Whitehead and Schwartzkopff works.

That in smooth water this torpedo is an accurate and most effective weapon there can be no doubt. Its commercial success is sufficient warrant for such an opinion.

The present speed of the Whitehead is from 23 to 25 knots for a range of 400 metres, and the variation in trajectory permitted at this distance by some Governments has been reduced to a few inches in the vertical direction. The lateral deviation allowed amounts to several feet.

THE USE OF GUNPOWDER FOR EJECTING THE WHITEHEAD TORPEDO.

The use of gunpowder for the discharge of the Whitehead torpedo is now almost universal[redacted] in the French navy. In other countries it is used to a less degree, although many boats recently built for different powers have been fitted with gunpowder-discharging apparatus. The charge used is small and only sufficient to discharge the torpedo from the tube and clear of the boat. The charge is attached to the inner side of the closing-door of the tube, and is discharged by an electric primer.

In Germany, gunpowder has found no favor for this purpose, compressed air being preferred, for the following reasons:

First. Compressed air is much more uniform in its action than gunpowder, and does not heat the tube, while the heat derived from the combustion of the powder increases the windage by expanding the tube, thereby causing variations in the rate of discharge, which, for accurate shooting, should be uniform.

Second. The sudden shock from even a small charge of slow-burning powder is sufficient to endanger the delicate mechanism of the torpedo.

Third. Air pressure is essential for charging the reservoir in the torpedo, and is always at hand, therefore, to eject the torpedo from the tube, and is consequently more convenient than gunpowder.

POSITION OF FIRING-TUBES IN VESSELS.

As to the location of torpedo tubes, below or above water, the practice in Europe is about equally divided. When the tube is in the stem it is generally placed below water. In Germany, however, the under-water tubes are preferred. These are placed when practicable with the interior arrangements, about three feet below the surface, and are considered most efficient when fixed. To properly charge and adjust a torpedo is of itself a delicate operation, and, in the opinion of those in favor of fixed tubes, as much as should be attended to below; the direction of the torpedo being controlled by the helm and its discharge by electrical communication from the deck.

Training tubes are much more generally used now than formerly.

THE HOWELL TORPEDO.

During the summer and autumn of 1885 the Howell torpedo was twice tried. The first trial took place at Newport, and was unsuccessful. The torpedoes were lost in deep water, and were not recovered. The second trial took place at Michigan City, where the facilities for such experiments were considered particularly good. Considering the disadvantages under which preliminary trials of this nature are made, the results were very satisfactory, and indicate the value of the weapon, even in its present state, and give promise for future improvement. The chief deficiency of the torpedo tried, when compared with the Whitehead, is that of speed. This defect will undoubtedly be greatly overcome in new torpedoes. Heretofore plane-bladed screws have been used to propel the torpedoes tried, and great speed was not expected. The fly-wheel develops sufficient power to propel the torpedo at a speed equal to that of the Whitehead, provided suitable propellers, capable of expending the power within short intervals of time, are fitted.

Lieutenant Couden, United States Navy, witnessed the experiments on the part of the Bureau of Ordnance of the Navy Department.

In his report to the Chief of that Bureau, he says:

"The launching apparatus acted well throughout the trials, except that the stirrups did not always let go simultaneously as they should. This was undoubtedly due to the material of which they are made and their slightness.

"The *accelerator* or *motor* gave trouble at first, owing to the tight packing, and probably in a measure owing to the use of some old packing with consequent heating. When repacked with new material it entirely ceased to give any trouble.

"The launching apparatus, including the motor, was readily put in place with the necessary steam connections.

"I see no reason to modify the report of the Torpedo Board in reference to the efficiency of the 'directive force' inherent in this torpedo, directing it in the same course it has when leaving the launching apparatus.

"SPEED.

"But two trials were noted. Others would have taken place, except that it was difficult for a single observer to catch the torpedo (under water) at the instant of crossing the imaginary line opposite his station, and attend to marking the time on the stop-watch. The distances were not less than noted, and were determined from fixed objects and a chart; scale 100 feet to 1 inch. As was to be expected, an increase of speed was shown for an increased time of steam on the motor. Steam on motor forty seconds giving 13.34 knots, and on motor for sixty seconds giving 15.6 knots.

"The propellers remained the same during all the trials. The blades are plane surfaces, are placed at an angle of 71° 31′ to the shaft; the surface of each blade is 3.25 by 1.5 inches, and each propeller has two blades. Such propellers are not probably well adapted to give speeds; at least, before it is decided that the best speeds attainable has been reached, other propellers of varying pitch and surface and of approved designs should be tried.

"THE DIVING APPARATUS, AND DIRECTION IN A VERTICAL PLANE.

"The buoyancy of the torpedo was 10 pounds in a weight of 284 pounds. It is evident that this buoyancy will exert a constant effort to bring the torpedo to the surface. The weight of the torpedo falling from a height gives it momentum which will carry it below the depth at which it is intended to run. There is nothing to interfere with this until the set depth is reached, after which it must be gradually overcome. The buoyancy deadens this action in a measure. The height from which the torpedo is dropped affects the momentum.

“The diving apparatus consists of a diving rudder and the means of throwing it into action. The power of working it is taken from a propeller shaft by a worm and gear. * * *

“This matter has been explained at some length to draw attention to the small amount of the work done by automatic device, and the simple character of that work.

“During several trials the torpedo was seen for considerable distances while running under the water, and in every such case it was apparently on an even keel, about 4 feet (the set depth) below the surface. If it were rising or diving the angle was too small to be appreciated by the eye under the circumstances.

“The torpedo was tried in water varying in depth from 16 and 18 to 12 feet, usually about 16 feet. It had a buoyancy of 10 pounds, was set for 4 feet immersion, and was dropped from a height of 5 feet 3 inches. Under such circumstances the diving apparatus must act promptly and effectively to produce the results observed.

“It is well known that difficulty is experienced with another torpedo of the automobile variety * when it is attempted to run it near the surface, and that it is usual to run it at not less than 3 metres (9 feet).

“THE TORPEDO AND ITS HANDLING.

“The torpedo tried was 8 feet 11 inches total length, 13.75 inches greatest diameter, weighed 284 pounds, had a buoyancy of 10 pounds in fresh water, and carried 40 pounds of lead to represent weight of explosive charge; the same torpedo in salt water would carry 60 pounds of charge without any buoyancy. It made a speed of 15.6 knots for 200 yards, and a total range of 500 yards.†

“The men who handled the torpedo had never seen it before, and were not specially selected; two were laboring men out of employment and the others were tug hands. They were entirely satisfactory and efficient. The repairs and overhauling were done by men who were also entirely inexperienced as regarded the torpedo; they had no difficulty in doing the necessary work without any special tools or appliances.’

No. of trial.	Steam pressure.	Time on motor.	Range.	Rose at, feet from start.	Horizontal direction.	Remarks.
	Pounds.	*Seconds.*	*Feet.*			
	50	20	1,200	No rise.	Straight	
2	60	40	1,428	100	......do	For about 200 feet could not see wake abreast station, indicating a constant depth.
3	65–62	40	600	Near start.	45 degrees to port	Supposed to have struck bottom in 12.5 feet of water and was heading broad to port when it rose.
4	70	40	Lost.	100	Straight	Could see wake for good part of run.
5	74–71	50	450	100–150	......do	Found rear compartment partly adrift.
6	72–69	30	750	100	......do	From station midway on course could see the torpedo for 100 feet running 4 feet under water.
7	70	30	750	50–100	......do	Do.
8	64–60	30	750	725	......do	When it rose it was pointed to left, of course having run straight up to 725 feet. Only 11½ feet of water here.

* Whitehead.

† With plane blades.

No. of trial.	Steam pressure.	Time on motor.	Range.	Rose at, feet from start.	Horizontal direction.	Remarks.
	Pounds.	*Seconds.*	*Feet.*			
9	65–62	30	100			Struck bottom 16 feet water, and stuck till exhausted.
10	65	30	1,150	200	Straight	Same results as in 6 and 7.
11	70–66	40	Lost.	150–400	do	Speed about 13.34 knots.
12	78–70	60	400	100	35 feet to starboard in 400 feet.	Diving-rudder pin broke before launching. Torpedo went to bottom and disconnected starboard propeller.
13	70	30	600	150	To starboard	Did not drop fair, but pointed to starboard.
14	70	30	150			Struck bottom and stuck, till exhausted.
15	70	30	700	150	50 feet to starboard in 700 feet.	Did not drop fair, starboard stirrup held too long.
16	75	40	700	No rise.	Straight	
17	62	40	850	No rise.	do	
18	70	40	890	200	do	
19	70	40	890	870	Slightly to starboard	Did not drop fair.
20	77–71	60	1,598	350–1,300	Straight	Speed 15.6 knots.
21	74–68	60	800	200	45 degrees to starboard	Starboard propeller adrift.
22	70	15	600	No rise.	Straight	
23	68–65	30	900	No rise.	do	
24	58	60	100		45 degrees to starboard	Starboard propeller adrift and its blade and shaft sprung, propeller having fouled its inclosing cylinder.

The following tabulated statement of the principal characteristics of the Whitehead and Howell torpedoes is taken from the excellent article on "Torpedoes for national defense," by Lieut. W. H. Jaques, U. S. Navy.

Particulars.	Whitehead.	Howell.
Length	14½ feet	9 feet.
Diameter	14 inches	13.5 inches.
Weight	594 pounds	304 pounds.
Speed	25 knots for 200 yards, and 21.5 knots for 600 yards.	15.6 knots for 200 yards with plane blades.
Power developed	133,551 foot-pounds for 200 yards and 251,779 foot-pounds for 600 yards, as given by brake experiments.	370,000 foot-pounds most that has been developed with 168 revolutions of fly-wheel; no speed observed. At Newport 115 revolutions gave an energy of 176,000, and speed of 14.8 knots for 100 yards. The propellers were plane blades and run 5 to 8 minutes in water, and do not exhaust the power with sufficient rapidity. New designs will correct this, as there is no question about the energy which should be exhausted within a minute at furthest.
Weight of charge	41 pounds	60 pounds.
Range	200 to 600 yards	500 yards.
Inherent directive force.	None	Absolute.
Attachments and manipulation.	Costly and intricate, requiring expensive accessories.	Simple and inexpensive.
Regularity of submersion.	Effective	Effective.
Cost of manufacture.	Very expensive	Cheap.

SIMS-EDISON TORPEDO.

This torpedo, which is being tested with a view to using it in the harbor defenses of the United States, has lately had its powers so far increased that it stands among the first, if not the leading torpedo of the class that is controlled by an operator at a distant station. The trials of a torpedo carrying 1 mile of cable gave such good results that another carrying 2 miles was ordered and delivered. This torpedo made its first run July 18, 1885, but did not prove as successful as the smaller one. The defects have been mainly remedied, and five torpedoes are now being constructed, in which the makers guarantee to increase the speed and handiness.

The principal defect lies in the lack of sufficient speed, the best average attained during a run being only about 10.4 knots per hour. As to the power of the operator to control its motions, there can be no question. During the many trials at Willets Point it has run its full distance without accident, and has been guided to right or left, straight or in a circle, at the will of the operator. The last test of this torpedo was to determine its power to dive under obstructions, such as spars, &c. These trials were made in June, 1885, when a spar 57 feet long was anchored about one-fourth of a mile from the launching station. The torpedo was guided so that it struck the spar almost in the center, dived under and passed it uninjured. A second trial was even more successful, for in this the torpedo was so accurately steered shat it struck the spar within 18 inches from the point at which it struck on the first trial.

The one-mile torpedo is 28 feet long by 18 inches in diameter, while the two-mile torpedo is 28 feet long by 21 inches in diameter, each being constructed in four sections, easily and quickly put together by means of lock-joints.

The hull or torpedo proper is maintained at a constant depth by means of a copper float; this is connected with the torpedo by means of steel rods supporting it at a distance of 5 feet below the surface of the water. Placed fore and aft on the float are two guide-rods fitted with a hinge and spring so as not to be injured by passing under obstructions while they resume their original position after the obstruction is passed.

Both torpedo and float are protected from cables, booms, or such obstructions by a sharp steel blade standing at an angle of 60 degrees with the surface of the water and connecting the torpedo and float at the forward and after ends, thus causing the torpedo to dive under or cut through obstructions.

The weights complete are 3,000 pounds for the small and 4,000 pounds for the large torpedo; no section weighs more than 800 pounds.

The power used is electricity, by which the torpedo is steered, propelled, and fired. For this purpose the 11,000 feet of cable contains two copper wires, one controlling the movements while the other conveys the motive power.

The bow section contains the explosive charge, which for the larger size is 400 pounds.

THE PATRICK (OR IMPROVED LAY-HAIGHT) TORPEDO.

The Patrick torpedo is made of copper, 36 feet long and 22 inches diameter. It is kept at a depth of 4 feet below the surface by means of a float, also made of copper, which is 42 feet long, 10 inches in diameter, and filled with lamp-black. The motive power is carbonic acid gas, which is contained in a liquid form in a large wrought-iron flask about the center of the boat. From this flask the gas passes, by means of long coils of copper pipe, through three chambers where an intense heat is obtained at the proper moment by the action of dilute sulphuric acid in quick-lime. The highly expanded gas then passes to a six-cylinder engine which drives the propeller. The speed of the torpedo is 20 miles per hour and is greatest at the end of the run. The range is one mile. It is perfectly controlled from the shore by an electric cable containing two wires. Trials are now being made at College Point, New York, before a commission of French officers. Trials before a commission of Turkish officers have just been completed.

PAULSON'S TORPEDO.

This torpedo differs mainly from others in its automatic steering-gear, by which it is kept on a set course notwithstanding any temporary cause of deflection. This is accomplished by means of a compass in the forward end, on which the course is set. By electric connections with the compass and the two driving propellers one of them is slowed as soon as the compass-needle leaves the bearing on which the card is set. By this decrease of the speed of one of the propellers the torpedo is brought back to its course and both propellers revolve again at a uniform speed.

A constant depth is maintained by means of diving rudders controlled by hydrostatic pressure similar to most other torpedoes. The speed, which is claimed to be as great as 25 to 30 knots, is obtained from the force derived from liquid carbonic acid, which throws jets of water through turbine-wheels, on the shafts of which are the driving-propellers. The speed is also increased by the streams of water and acid which pass out through the shafting.

An experimental torpedo built on this design has been tried, and those interested in its development claim that it maintains its high speed and straight course, though none of the particulars of the trial have as yet been made public.

BERDAN TORPEDO.

The main feature of this system lies in joining two rocket-driven torpedoes by a small steel wire about 10 or 12 metres long. Each torpedo has its own motive power, but that one designed to lead, having the greater speed, tows the other. For convenience the leading torpedo is called A and the rear one B. Either or both may carry the explosive charge.

The object of this design is to cut through or dive under such obstructions as nets, &c., which are placed around ships for their protection against torpedoes, and can only be effective when the object of attack is close to the obstruction.

The system acts in two ways. When A is charged it strikes the obstruction, and, exploding, opens the way for B, which, continuing on, explodes against the bottom of the ship. When A is not charged it strikes the obstruction, and, becoming entangled, serves as a center upon which B revolves, passing under the obstruction, and coming up strikes the ship's bottom and explodes. This last arrangement, the inventor claims, will give the best results. It is accomplished as follows: In the torpedo B is a small diving-rudder, which is held up and out of gear as long as the connecting wire is taut ahead, but as soon as the obstruction fouls A the wire slackens, releasing the diving-rudder in B, causing it to dip down at an angle of 15 degrees, and so it continues until the tow-line is taut astern, when the rudder is changed to ascend, steering B up against the ship's bottom, point first.

When there is no obstruction the ship's side arrests the progress of A, slackens the tow-line, and B dives as before, which gives a more damaging explosion, as by dipping under the bottom it not only strikes in a weaker part of the ship, but, from its greater depth, exerts more force, while the A torpedo strikes but little below the water-line.

The motive force is derived from the combustion of a composition of powder and clay, which is compressed into twelve separate tubes, each containing 100 pounds of the mixture. This composition burns 2½ minutes, driving the topedoes 1 mile at the rate of 24 knots per hour.* The gas derived from the combustion exerts a pressure of 2,000 pounds per square inch, and is transmitted through a nozzle, and acts upon several compartments of a turbine which revolves the propeller.

The torpedo A has steering-gear, while B has none. Two small plaited lines lead from this gear in the torpedo to the operator, who, by hauling on one or the other, steers the torpedo to right or left. To assist the operator, A travels close to the surface and carries a rod about a yard long, with a ball on it for a day run and a light (which shows only to rear) for a night run. The torpedo B is regulated to run at a depth of about 5 feet under water.

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* Estimated.

The general dimensions are as follows: Length, 31 feet; beam, 20.8 inches; depth, 31.5 inches; weight, 2,860 pounds; weight of charge, 220 pounds.

TORPEDO NETS.

The only practical way yet devised of keeping torpedoes clear of a ship's side, either while under way or at anchor, is some system of netting.

Rear-Admiral Edmund R. Fremantle, of the Engish navy, in a lecture on Naval Tactics, mentions torpedo-netting in the following language:

"There is a natural inclination to laugh at them as unpractical; they take up room, they are an awkward incumbrance to movement, the commander finds that they are an interference with the royal-yard drill, and that they scratch the ship's side; the staff commander finds they will foul the screw; the dock-yard authorities find them a tax upon their ingenuity as well as a source of expense for which they get little immediate return, yet slowly but surely they are being adopted; the difficulties of working them are being overcome, and their importance is being acknowledged.

"The problem of getting these nets o t is being effectively solved in the Mediterranean fleet under Lord John Hay, who has given much attention to this important question. I do not know if the bow and stern defense, several plans for which were being tried a year ago, has been settled, but I know that the broadside defense by nets has been successfully carried out. In the Dreadnought we had a broadside defense fitted according to a plan of Staff Commander Miller, and I was able to steam with it at a speed of 8.5 knots without danger, though at that speed the nets undoubtedly sagged aft considerably. The plan can scarcely be explained in few words, but I may mention that the ship answered her helm well when using the nets, the loss of speed being only about half a knot, and that when they were once out they could be brailed up and the booms run fore and aft in about one minute, or got out again equally quickly; also, that with the booms fore and aft they could be carried, as indeed they were in the Agamemnon, without material damage in bad weather."

An invention of William M. Bullivant, of England, seems to cover every point in attaching and working torpedo-nettings. His plan may be briefly described as follows: Heavy iron tubing, hinged on the ship's side with a universal joint, acts as a boom or outrigger; on this travels a car, which is moved out or in by a single line; that for rigging out passing over a sheave at the boom-end. The boom is lowered or topped up by a topping-lift, similar to those fitted to swinging-booms. A steel hawser runs through an eye on the lower side of the car; to this hawser the netting is attached by sister hooks. The booms are so placed that when triced up they may be used as awning stanchions. The ridge-rope for the awning is secured to the heads of the booms, so that when they are down the ridge-rope acts as a span for supporting the spars, and at the same time lends an additional protection in stopping torpedo-boats before reaching the net.

The net is rigged in by simply tricing up the booms when its own weight brings it in as soon as the outhaul is let go. In rigging the net out, the operation is greatly assisted by lowering the head of the boom below the heel.

The netting is composed of light steel rings, joined by smaller ones.

The advanced practice of defense is to provide armored ships not only with torpedo-nets, but with the means of laying out a line of small mines to surround the ship.

The English nets are usually 15 feet on the head by 20 feet in depth. The French plan of fitting nets 20 by 20 feet seems preferable, as avoiding confusion.

As a rule, the booms are spaced at intervals of about 45 feet, and vary in length from 21 to 29 feet. The nets are usually fitted with brails.

TORPEDO-BOATS.

ENGLAND.

During the year 1885 there were fifty-four first-class sea-going torpedo-boats laid down for the British Admiralty. Forty of those were ordered early in the summer from Thornycroft and from Yarrow; they are the 125-foot 19-knot boats described on page 134. Yarrow has been delivering them lately at the rate of two a week. This same firm has also received an order to build one in all haste similar to the Austrian Falke, described on page 132; it is claimed that they will produce a boat superior to it in speed and some other respects. J. S. White has also furnished several of his turn-about type for the Admiralty and for some of the colonies.

A very shallow-draught twin-screw boat has been built by R. Smith for the defense of the Indian coast; the longest is 62 feet; beam, 12 feet; draught, 2½ feet; displacement, 22 tons; I. H. P., 170; speed, over 15 knots. The torpedoes are fired from a tube forward.

FRANCE.

During the year 1885 there were built for the French navy by Normand & Co. ten boats, numbered 65 to 74. They are 108 feet long, of 50 tons displacement, and the guaranteed speed was 20 knots, which was exceeded in almost every case. Their most distinctive feature is the armament, the tubes for Whiteheads being supplemented by a spar for the outrigger torpedo, the usual buffer being provided forward. It was also stipulated that their draught and the height of structures on deck should be so proportioned as to permit their passing through the canals and under the bridges from the Bay of Biscay to the Mediterranean; to this end the smokestacks can be reefed down to the height of the pilot house.

In the latter part of 1885 there were ordered from different private builders thirty more boats, to be numbered 75 to 104. These were of the 111½ foot type, and were intended primarily for the defense of Cherbourg, Brest and Toulon. Since then there have been ordered thirty-seven more—ten from the Forges at Chantiers, Havre, six from the Chantiers de la Gironde, five from Le Creusot, and sixteen from the Forges et Chantiers, La Seyne. They are of the 35-metre type (114¾ feet), and the stipulated speed is 20 knots, a penalty attaching to each tenth of a knot below that; less than 18 knots would cause the rejection of the boat.

Normand has also been building three of a larger size, 133½ feet in length, 11 feet beam, 67 tons displacement. Their speed, with full outfit and coal enough to make 1,000 knots at 11 knots, is to be 19 knots.

GERMANY.

In the spring of last year the German Reichstag appropriated $4,200,000 to buy 70 torpedo-boats and their armaments. According to the plan proposed, the whole number is to be 105.

A large proportion of Government orders are now given to Schichau, whose recent boats have been so successful in point of speed, endurance, seaworthiness, and handiness. They are mostly of the 85-ton type, make over 20 knots with a load of 14½ tons, and can steam 3,000 knots on their own coal. The proportions of length to breadth are less than in the boats of most other builders—which may account for their good behavior at sea. They turn in about 220 yards.

Two 220-ton boats have also been ordered from the same firm for the German navy.

AUSTRIA.

The two most prominent additions to the Austrian torpedo flotilla are the Falke and Adler, built by Yarrow (see page 132). They made 22.3 and 22.4 knots, respectively, loaded as for service, and are considered by many as the most advanced step made so far.

Schichau has also built two 90-ton boats for the Austrian navy, to make 20½ knots with a load of 14½ tons, and to carry coal enough for 3,500 knots at 10 knots.

RUSSIA.

At the beginning of this year there were 36 first-class torpedo-boats building for the Russian navy in different countries. Schichau had in hand nine 90-tonners, of 20-knot speed, loaded, and 3,500 knots endurance at 10 knots. Four of these just delivered have proved remarkably successful, one of them averaging 22.24 knots for six hours. Another attained a speed of 23 knots, under the usual conditions of 14½ tons of ballast, coal for 1,200 miles, and a crew of 18. This shows Russia to possess at this moment the fastest torpedo-boat afloat. Normand is building two of 153½ feet length, 100 tons displacement; guaranteed speed, 19 knots. Schichau is also building three smaller ones, 118 feet long, 16½ feet broad, to make 19 knots, and steam 1,200 knots at the rate 10 knots an hour.

The private dock-yards of Russia are now beginning to build a good many also. At Nikolaieff ten have recently been in hand of the French type, to make 20 knots; and two have been built on the Neva 127 feet long, of 19 knots speed. At Cronstadt one has been produced 135 feet long, 70 tons displacement, and is said to be very handy, having twin screws and two rudders.

SPAIN.

Spain relies principally upon English and German firms to increase her torpedo fleet. The Orion, built by the Germania Works, Kiel, has already been described, page 133. Last November two 125-foot Thornycrofts left for Carthagena. The Retamossa, recently completed by Yarrow, is 118 feet long by 12.3 broad, and maintained 20.26 knots for three hours. Two 115-foot boats, of 18 knots speed, have also reached Bilbao from England. Two more first-class boats have recently been ordered from Thornycroft, and two from Yarrow, the latter to be similar and equal to those recently built by that firm for Austria. Their guaranteed speed is in fact 23 knots in fighting trim, with 17 tons on board, and 25 knots running light. Normand will also deliver a 127-foot boat before long, of 66 tons displacement, to make 18½ knots fully equipped.

The torpedo-boat-building industry is also progressing in Spain.

ITALY.

There are at present building for the Italian navy in domestic and foreign ports twenty-eight sea-going torpedo-boats, to be numbered from 56 to 83. The numbers will probably be brought up to 100 by the end of the year. Schichau builds four of 90 tons displacement, 21 knots speed (loaded), 3,500 knots endurance. Six of similar type are being built by Pattison & Co., and two by Guppy & Co., in Naples; four by Cravera & Co., in Genoa, and four by Odero & Co., of Sestri a Ponente. Yarrow is engaged on two 140-foot twin-screw boats, described on page 133, and two of the same type are building at the naval dock-yard in Venice. Odero & Co. are also building four 100-foot boats of the Thornycroft type.

An electrically-propelled launch has been ordered from Yarrow for the purpose of testing the merits of that system of propulsion.

GREECE.

The torpedo-boats now being supplied to Greece are all of the sea-going type; six of these, built in Stettin, recently completed the voyage to the Piræus. Their principal dimensions are: length, 123 feet; beam, 15 feet 3 inches; draught, 6 feet 6 inches (aft); displacement, 85 tons. They are fitted with engines of 1,000 I. H. P., propelling them at a maximum speed of 19 knots. They met with heavy weather in the Skagerack, North Sea, Channel, and Bay of Biscay, in which they behaved well, and are said to have arrived at the Piræus in good condition. Two of the boats were detained from ten to fourteen days by collision and grounding, but the other four made the voyage in twenty-one days, including stops at Yarmouth, Plymouth, Gibraltar, and Malta for coal.

TURKEY.

Turkey has been pushing her naval development considerably in the direction of torpedo-boats, being impelled to that course, probably, by the laying down of the heavy Russian armor-clads. The boats ordered a year ago from the Forges et Chantiers, La Seyne, gave such satisfaction that a number more were ordered abroad, and several were begun at the Rupinal Arsenal on the French model, the engines being English built; one has been launched, and made 18 knots. Five recently sailed from German works, which, at their trials at Pillau, proved to be remarkably successful. These were built by Schichau, of 85 tons displacement, and one of them averaged for two runs over a 20-knot course, 22.96 knots; with one exception they all averaged over 22½ knots fully equipped. The engines are of the triple-expansion type, and the consumption of coal was very small, their endurance being proportionately increased. At full speed, with bow and stern rudders, their turning circles are about 495 feet in diameter.

HOLLAND.

Three sea-going torpedo-boats are now building in Holland—one by the Government works, at Amsterdam, and two by private firms; Yarrow also has one in hand. The intention was to provide nine of these by the end of the year, but that will not be carried out. The programme calls, eventually, for twenty-six first-class boats and twenty-four smaller ones. Most of the latter are now on hand, of English build.

CHINA.

China has been giving her late orders for torpedo-boats to German firms. During the past year nine of the second class were ordered from Schichau; these are of 26 tons displacement, 19 knots speed, and 1,000 knots endurance at 10 knots. A 115-ton boat, described on page 133, was also ordered from the same firm. Yarrow is now building one, too.

One of China's first-class boats, built at Stettin, was recently disabled by a curious accident: while steaming at full speed near Canton the fly-wheel of the fan burst killing the engineer, bending the crank shaft, breaking the guides, and knocking a 6-inch hole in the bottom.

JAPAN.

There is being built in England for Japan one of the most prominent torpedo boats of the day: see page 135. Thirty-eight boats in all have been ordered from English firms, of which about one-half have been delivered.

CHILI.

Chili has begun again to increase her torpedo fleet, an order having been given to Yarrow for a 120-foot boat, to be fitted with tubes for discharging fish-torpedoes.

THE TRIAL OF THE NORDENFELT SUBMARINE BOAT AT LANSKRONA IN SEPTEMBER, 1885.

The Nordenfelt submarine boat has been described in General Information series No. IV. It was tried at Lanskrona in September last, in the presence of a number of naval and military officers, representing many foreign governments.

The first trial took place on the 22d September. The submarine boat was towed out from Lanskrona by a steam-launch, and in casting off when outside the fort her bow rudders were fouled by the tow-line. This somewhat crippled her vertical steering power and rendered repairs necessary before diving to any depth. A trial on or near the surface was made in consequence, during which the boat's power for partial submergence was illustrated. Moving at a speed of 5 knots she steamed around the Edda (on board of which were the officers witnessing the experiments) and showed good steering qualities. She was frequently submerged to a depth of 5 feet, disappearing below the surface in half a minute, but remaining below for short periods only.

On the second day the boat steamed on the surface about 10 miles from Lanskrona.

On the third day, in a calm sea, she exhibited her power of moving under the surface, covering distances of about 300 yards on each occasion, the periods of disappearing not exceeding four and a half minutes.

The boat, when at light draught, upon the calm surface, was scarcely visible at 1,000 yards, although, in spite of her light gray color, the coamings supporting the cupola, &c., were noticeable, and the swash of the screw attracted attention. It was thought by the observers that the boat could thus (with only the upper surface of boat and cupola above water) approach unseen to within 1,500 yards. The process of closing the boat and sinking to deep draught (the upper surface just awash) occupied about twenty minutes. In this position the cupola is the only part visible, and if discovered offers but an extremely small target. At a depth of 5 feet the boat was noticeable only as a shadow upon the surface of the water, although from the tops of the Edda she was distinctly made out at a distance of 600 yards. The observers, however, knew her exact position upon diving, and consequently were enabled to follow her movements.

Among the defects noted in this boat may be mentioned the following: The speed attained below the surface was extremely slow; in fact, only three knots was claimed by the inventor; the period of twelve hours, required to raise the necessary pressure for underwater steaming, is excessive; the vertical coaming offers a conspicuous mark; there are no means of getting out of the boat when submerged.

Since these trials the Greeks have purchased one of Nordenfelt's boats. It has been tried at Athens, and has been worked at a depth of 30 feet. On one occasion four men remained in the boat submerged for six hours. The contract speed of 8½ knots was easily accomplished, and the boat made a run of 10 miles on steam stored in the reservoir.

The Turks have recently ordered two boats of a larger and more improved type than that tried at Lanskrona. The Turkish boats are fitted to discharge two Whitehead torpedoes, while the Greek boats can fire but one.

Mr. Nordenfelt thus described the larger type of boat before the Royal United Service Institution in February last:

"Length, 100 feet; beam, 12 feet; displacement, 160 tons; speed on measured mile, 12 knots; distance traveled without recoaling, 900 miles;* depth to which it can safely descend, about 50 feet." (The speed under water is not stated.) "Engines, condensing-compound; at steam pressure of 100 pounds to develop 250 horse-power. The smoke is discharged under water. To carry two 14-foot fish-torpedoes outside on bow, to be mechanically discharged. Sinking-screws driven by two engines, each indicating 6 horse-power. Coal-bunkers on the sides of boiler. Crew of six men. With coal in the bunkers only, this boat can keep the sea for five days or more."

It is proposed to tow one of Mr. Nordenfelt's controlled electrical torpedoes.

In the discussion on this paper, Admiral Arthur, at one time naval attaché in Washington, expressed himself in these words:

"We want torpedo-boats that can steam at a high speed, with almost total immersion. Undoubtedly to do this they must have the power of going entirely under water; but such should be exceptional and for very short periods. My opinion is that all torpedo-boats should be submarine boats; that is to say, they must have the power of going under water if required, but they must be able to steam at a high rate of speed along the surface. I should think we may eventually arrive at being able to solve the question of maintaining the same speed they have at present, viz, of 20 knots an hour; we should get that at a light draught, for which some alteration in the position of the screws would be necessary; then, with the turtle-back awash, we should get 13 knots; and we may be quite satisfied with 6 knots or less on total immersion."

Admiral Sir Cooper Key stated: "I believe that this submarine boat has a great future, and that Mr. Nordenfelt has achieved a great success."

TUCK'S SUBMARINE TORPEDO-BOAT.

This is the design of Mr. I. L. Tuck, and was built at the Delamater Iron Works in New York City. The dimensions are as follows: length, 30 feet; beam, 7.5 feet; depth, 6 feet. The general shape is similar to most submarine boats. The distinctive feature is a well in the center of the boat fitted with an air-tight hatch, which can be opened from the inside. The operator, wishing to go on deck during the time the boat is submerged, puts on a diver's suit, enters the well, closing the door behind him, and allows it to fill with water when the hatch leading on deck is opened. An air-pump in the interior supplies his helmet with air by the usual means. In the well there are arrangements for directing the boat.

Besides the usual weights, this boat carries a quantity of lead, leaving but a slight excess of buoyancy. This is entirely overcome, when wishing to descend, by the admission of sea-water into suitable tanks.

Compressed air stored in a reservoir of piping supplies the boat with fresh air.

The propeller is worked by an ordinary dynamo, run by storage batteries, which also furnish electricity for the incandescent lamps in the interior. There are both horizontal and vertical rudders, worked by hand from the outside or inside.

The object of this boat is to descend when near a hostile vessel, run under her, and release two torpedoes connected by electric wires, the boat being guided and the operation of releasing the torpedoes being performed by a person standing in the well. The boat then moves off to a safe distance and explodes the torpedoes by electricity.

Some preliminary trials have been made to test the working of the engine and the ability to remain under water, but no information of any extended trial has been made public.

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* Probably the estimated speed and distance.

THE GOUBET SUBMARINE TORPEDO-BOAT.

The Goubet submarine torpedo-boat is of iron, 16 feet 5 inches long, 3 feet 3½ inches wide, and 5 feet 10½ inches deep, including the lookout dome.

The weight of the boat, with its water reservoirs empty and without the crew, is 3,196 pounds (1,450 kilograms), and its displacement when submerged is 4,056 pounds in sea-water (1,800 liters). Its buoyancy is therefore 860 pounds, and the boat is submerged by the weight of the crew and the water admitted to the reservoirs.

Each man requires about 400 litres (14 cubic feet) of air per hour. To provide for this a reservoir contains air at a pressure of 50 atmospheres, in sufficient quantity to last the crew of two men for 10 hours. The carbonic acid and the other acids are absorbed by chemicals, and an air-pump expels the foul air.

To drive the boat at its maximum speed of 5 knots a power of 42 kilograms (.553 H. P.) is required, and may be furnished by a Siemens motor, working from accumulators. (This would necessitate a weight of 4,000 pounds for motive power.)

There is no rudder, but a universal joint in the screw-shaft permits the screw to move through an arc of 90° on each side.

In submarine boats it is essential that the trim should be very exact, as otherwise the motive power might cause the boat to jump out of water or dive to unsafe depths. To maintain the trim in the Goubet boat there is a water-tank at each end of the boat connected with a double-acting pump, which draws and delivers in opposite directions, according to the direction of motion of its operating shaft. This shaft ends in a crown wheel, which may gear with either of two wheels on a shaft at right angles to the first, and revolving constantly in the same direction. As long as the boat remains with its axis horizontal the pump is motionless, but on any change of the axis a pendulum throws the pump into gear with one of the two wheels on the second shaft, and water is pumped from the lower to the higher tank, bringing the boat to a level axis.

The torpedo is carried outside the boat and is secured by a bayonet-catch controlled from the inside. On arriving under the enemy the torpedo is released and rises by its reserve of buoyancy until it catches on the vessel's bottom by spikes, with which its upper surface is provided. The torpedo-boat then withdraws, maintaining its connection with the torpedo, by unreeling a wire. When the boat is at a safe distance the torpedo is exploded.

The boat is also provided with a small torpedo which, when released, rises to the surface and explodes, forming a signal which by its noise and the color of its flame calls attention to the boat and indicates the depth at which it is. The torpedo may also carry up a telephone wire.

A large weight is attached to the bottom of the boat by a screw and nut, and may be released at any time, thus permitting the boat to rise.

In case the motor breaks down there is an arrangement for working two oars which habitually trail alongside. These oars fold longitudinally. When in use they open at the stroke and close at the recover.

To attack a vessel the boat proceeds along the surface until it is thought necessary to dive, when the captain directs the boat at the enemy by the sight-vane; the other man maintains the course by compass, and the boat sinks by admitting water to the tanks.

It is stated that three hundred of these boats were ordered for Russia in 1881, and that fifty were delivered in 1883. The early form of the boat was driven by manual power.

ADDENDUM.*

[The continuation of the narrative of the French Naval Manœuvres, p. 21.]

The grand manœuvres began on the 10th of May, and the neighborhood of Toulon was the scene of operations. For the time being the fortifications of Toulon were supposed not to exist, the port and roads being defended by the torpedo division only, as indicated by the first theme.

As no map accompanies this account, it may be well to describe briefly the locality. The inner port of Toulon is nearly landlocked, and the entrance to it is closed by a jetty or breakwater. The outer roads, extending in a WNW. direction, are about two miles wide, one mile long on the southwestern and about two miles long on the northeastern side. Cape Sepet is the headland marking the western side of the entrance to the roads, while Point Querquerane marks the eastern limit. Cape Brun lies on the north shore, nearly north of Cape Sepet, and about two miles east of the jetty. The Golfe de Giens lies just east of Point Querquerane, and at its southern limit are the Foumigues Rocks, 4 miles southeast from the same point. Hyères Roads are some 12 miles from the Toulon jetty, and are separated from the Golfe de Giens by a narrow strip of land.

Cape Sicié is a headland about 5 miles west of Cape Sepet.

The armor-clad squadron, under the command of Vice-Admiral Lafont, was divided into two divisions:

First division.—Colbert (flag-ship), Amiral Duperré, Friedland, Marengo, Milan (cruiser), and torpedo-boats Nos. 74 and 70.

Second division (Rear-Admiral Rallier).—Dévastation, Redoutable, Suffren, Vauban, Hirondelle (cruiser), and torpedo-boat No. 71.†

Division of torpedo-boats (Rear-Admiral Brown de Coulston).—Desaix, Aréthuse, Dupetit Thouars (cruiser), the Fulminant (armored), and seventeen torpedo-boats; twelve first-class boats of about 108 feet, and five second-class, of about 89 feet.

The squadron took station outside; the division of torpedo-boats inside, behind the jetty. The Fulminant was moored at the entrance to the inner port, close to the jetty.

The following themes indicate the nature of the operations and the methods observed in conducting them:

First theme.—Can a squadron of armor-clads approach by day and bombard a commercial or military port defended by a flotilla of torpedo-boats?

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* Taken from the French journals, chiefly from Le Yacht.

† The torpedo-boats of the squadron were supposed to be torpedo-catchers (*contre-torpilleurs*).

Second theme.—Can a division of cruisers, accompanied by torpedo-boats, force a blockade maintained by a squadron of armor-clads?

Third theme.—Can a squadron of armor-clads at sea, *en route* between Algeria and Toulon, be discovered and reached by a flotilla of torpedo-boats?

Rules to be observed during the manœuvres.

All vessels forming part of the squadron, *contre-torpilleurs* (torpedo-boats accompanying the armor-clads) included, will carry their running-lights at night. The enemy's (attack) torpedo-boats will not display their lights. Any ship placed *hors de combat* will hoist at the mizzen a flag or lantern to indicate this. These signals will be displayed during the entire time that the vessel is considered out of action.

Any torpedo-boat of the enemy found in any creek or indent of the coast by any vessel of the squadron will be considered as captured and sent to Toulon with a paper indicating its capture.

A torpedo-boat will be *hors de combat* (1) if it has been under the fire of 50 rounds of the Hotchkiss revolving cannon before being in position to discharge its torpedo; (2) if it has been under the fire of a single round from any other gun, provided the torpedo-boat has been seen at a distance of less than 500 metres, and in the prolongation of the line of sight of this gun which has been previously laid for a given direction and range, in expectation of an attack from torpedo-boats.

Any armor-clad not protected by its nets will be considered as out of action if it receives the fire of two torpedoes discharged by a torpedo-boat in good position at a distance of less than 400 metres.

Any armor-clad protected by its nets will not be considered as vulnerable except at the bow and stern: at the bow, under the conditions defined in last paragraph; at the stern, if the torpedo-boat has been able to approach and discharge its torpedo within short range of the armor-clad.

Any cruiser will be considered as captured if for one hour, at least, it remains under the fire of an armor-clad at a range of less than 2,000 metres, or if the vessel chasing shows a superiority of speed over that of the chase such that it can be overtaken one hour before nightfall.

Operations beginning on the 10th May, the electric lights were used from the shore, and all vessels and boats kept under steam at *all* times.

May 10.—The squadron cruising outside Toulon, standing off and on the entrance to the port. Fine weather. Smooth sea.

May 11.—Squadron off the entrance to port. Toward noon passed the entrance in column of vessels after having searched the coast by means of its cruisers and torpedo-catchers. The torpedo-boats did not go out. Wind fresh from NW. The squadron might have readily bombarded Toulon from two favorable positions.

May 12.—Nothing of interest occurred.

May 13.—Fresh breeze from the SE. Heavy sea breaking over the jetty or breakwater. Foggy. The squadron formed by divisions in two columns, the vessels of second column opposite the intervals of the first (our order of battle in two columns), *par division en ligne de file endentée*, and stood in toward the port. When five miles to the southward and westward of Cape Sepet the squadron cleared for action, and the second division was ordered to proceed to the Gulf de Giens, a few miles to the eastward of the entrance to Toulon Roads. In column of vessels the first division crossed the entrance to the roads to the eastern shore, when the head of column changed course eight points to port (NW.), and steered so as to pass to the westward of Cape Brun. The column again changed direction to port (SW.), and steamed in a direction parallel to the jetty, to which it was now quite close, and opened fire.

The Fulminant opened fire upon the squadron, and the torpedo-boats coming out through the jetty pass, a general engagement ensued. Some torpedo-boats, masked by the Fulminant, charged the Marengo, the rear vessel of the column, which received them with a heavy fire of great and machine guns. The state of the sea was such that the torpedo-boats could not have properly discharged their torpedoes. It is said that it would have been dangerous to open the tubes.

The time of attack was well chosen, and would probably have been successful, as the torpedo-boats were placed at great disadvantage, attacking by day and in a heavy sea.

The following are given in Le Yacht as observations worthy of notice:

> On the evening of the 10th we went out of Hyères Roads, about 10 o'clock. I am firmly of the opinion that the reflection of the moon upon the ripple of the water would have made it impossible to make out a torpedo-boat at more than 600 metres. On the 12th there was a night alarm. The sea was absolutely smooth. It would have been possible to distinguish, toward 2 o'clock a. m., a torpedo-boat coming from the eastward without lights; but in the west the sight was limited to a few hundred metres, and a silent torpedo-boat could have surprised us.
>
> On the day of the attack upon Toulon I am firmly of the opinion that our torpedo-boats could not steer in the rather rough cross-sea without reducing speed. As soon as 10 knots speed had been passed the bow disappeared under the sea, the stern lifted, and the boat tended to come head to wind.

This concluded the operations under the first theme.

For the second theme the operations were naturally conducted in a different manner. The crews were divided into three watches, so that a constant and effective lookout and preparation was not fatiguing. The cruisers and torpedo-catchers were at daylight sent to a neighboring bay (Hyères), so that the crews might obtain necessary rest. At night two of these boats were on the picket-line, while the third remained at its anchorage. On board the armor-clads two lieutenants were constantly on duty.

In the daytime the squadron cruised in column of vessels, in open order, at low speed. At night it was formed in three lines, as follows:

First line.—The Milan, under Cape Sepet, with its torpedo-catcher; the Hirondelle, at the other side of the entrance to roads, with a second torpedo catcher.

Second line.—Five armor-clads with their nets down, describing, about a point fixed by cross-bearings, circles of 1,200 to 1,500 metres diameter. Each day the direction of motion was changed to disconcert the enemy. The second line extended from Cape Sicié to the Fourmigues, a distance of about 7 miles.

Third line.—The armor-clads of high speed, the Duperré, Redoutable, and Dévastation, held in readiness to give chase to any vessel running the blockade.

The incidents of this part of the operations were varied by frequent night attacks of torpedo-boats and attempts on the part of the cruisers to escape. The torpedo boatmen claim many ships destroyed; but, on the other hand, it is averred by the officers on board vessels of the squadron that in many, if not most, cases the torpedoists were over-sanguine and discharged their torpedoes beyond effective range, and under circumstances of sea and weather altogether unfavorable and prejudicial to good firing. It is stated by those in the armored vessels that the torpedo-boats signaled discharges of torpedoes when at a distance of more than 1,000 metres; and as the opportunities of estimating distances from the armored vessels were much the best, this statement is instructive as illustrative of the difficulties under which an officer in charge of a torpedo-boat in a seaway must act.

On the night of the 17th the attempt to pass the blockade was made. The Fulminant, Aréthuse, Dupetit Thouars, and eleven torpedo-boats were under steam, ready to move. The weather was calm, though some-somewhat foggy, and the sea smooth.

The Fulminant, in company with seven torpedo-boats, passed along the shore of Cape Sepet, drove off the Milan, and allowed the boats to gain the offing. The Aréthuse, Dupetit Thouars, and four torpedo-boats skirted the eastern shore under the shadow of the land. These were discovered by the squadron and kept in view by the electric lights. By the skillful handling and feints of the Aréthuse, which drove off the Hirondelle and her torpedo-catcher, and drew the attention of the armor-clads, and the attacks of the torpedo-boats upon the Marengo and Suffren, the Dupetit Thouars slipped through the line, though in doing so she was under the fire of the Marengo, which fired at her fourteen rounds from her 24 centimetre and eight from her 14 centimetre guns. At one time the range was less than 1,000 metres. The plan of the attack was well carried out. The Fulminant and Aréthuse engaged the attention of the inner lines while the torpedo-boats attacked and perplexed the movements of the outer lines of armored vessels. While the Dupetit Thouars escaped, it is probable that in actual war she would have been seriously damaged, as she was in the beam of the squadron's search-lights and under its fire for some time.

The lessons in tactics thus far to be drawn from the yet unfinished manœuvres lie in the study of the formation of the French squadron for attack on May 13, and in the carefully devised plan of maintaining the blockade, as well as the formation and movements of the torpedo flotilla. The torpedo-boats were divided generally into groups of fours. They were manœuvered in groups by the steam whistle, which was given a different note in each boat of a group. The boats were also distinguished in groups by different colors—white, black, green, &c.

They were always accompanied by a heavy vessel and moved under her cover until the moment of attack, when they dashed forward upon the object of their search. The experience gained during two months of constant torpedo-boat work was noticeable in the increased skill and endurance shown by the crews of all the boats.

The narrative of the remainder of the manœuvres (after the 24th May), which will be watched with much interest, cannot, unfortunately, be given in this publication.

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